DISCLAIMER

The contents of this report reflect the views of the investigators and authors who are responsible for the facts and accuracy of the data presented. The contents of this report do not necessarily reflect the official views or policies of the state of California. This report does not constitute a standard specification, design standard, or regulation.

California Department of Transportation

Traffic Operations Program

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16. ABSTRACT

In Caltran's continued efforts to provide safe facilities for pedestrian travel, Caltrans decided to have a document compiled which contains the nation wide "best practices" related to pedestrian transportation and safety.

A nationwide literature search was conducted and the 50 State Departments of Transportation were contacted, as well as the 50 largest U.S. cities and 12 Metropolitan Planning Organizations. This document contains the best practices of these organizations.

The current practices of Caltrans are reviewed and compared to the best practices of the other transportation related organizations. Recommendations are made regarding practices that Caltrans should maintain, practices for Caltrans to study, and practices for Caltrans to implement. In addition, other general recommendations are made.

Specific recommendations include the development of a pedestrian count program. This will allow Caltrans to determine relative pedestrian exposure in the transportation facilities. In addition, it is recommended that Caltrans continue its pedestrian safety campaign. It is recommended that public education be focused on the specific causes of most pedestrian collisions.

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We would like to acknowledge the Pedestrian Safety Task Force which gave guidance and support for the duration of this project. The Task Force consists of representatives from the Federal Highway Administration, Caltrans' headquarters and district traffic engineering personnel, California Highway Patrol, California Department of Health and Social Services, California Department of Motor Vehicles, local and regional agencies, and affected citizen groups. The Task Force was formed to develop plans and programs aimed at improving pedestrian safety statewide.

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1.0 INTRODUCTION

Background

Historical Overview

Walking was the earliest form of human travel and remains the most basic. Throughout history, walking has been a fundamental part of all society and will continue to be important to human activity. An evolution of transportation modes has followed walking in an effort to advance human mobility and economic development. Many of the first roads originated from animal trails that humans began to utilize. In an effort to increase the level of transportation, humans began the process of domesticating animals such as horses and camels. These animals were used for both riding purposes and carrying goods. Evidence shows that around 4000 BC, roads of wood and stone were constructed to simplify the efforts associated with travel. Some modes that followed were rowed boats and wheeled carts, propelled by human or animal power. While these improved mobility, they were still primitive in nature. However, it is clear that some ancient societies, Egyptians and Phoenicians, realized the association between transportation and economic development. (*20*)

In present day California, one may consider the number of employment and recreation opportunities that are available within a 45-minute walk. These opportunities can be compared to opportunities available by bicycle, bus or car. Clearly one who travels by bus or car has many more opportunities. With all the modern transportation modes including automobiles, airplanes, buses, ships, and trains, it is often forgotten that walking is still an integral portion of all travel. Even trips of long distances begin and end with walking. People walk 1) to and from their cars, 2) to board a bus or train, 3) to access a ship, and 4) through airports to and from the aircraft.

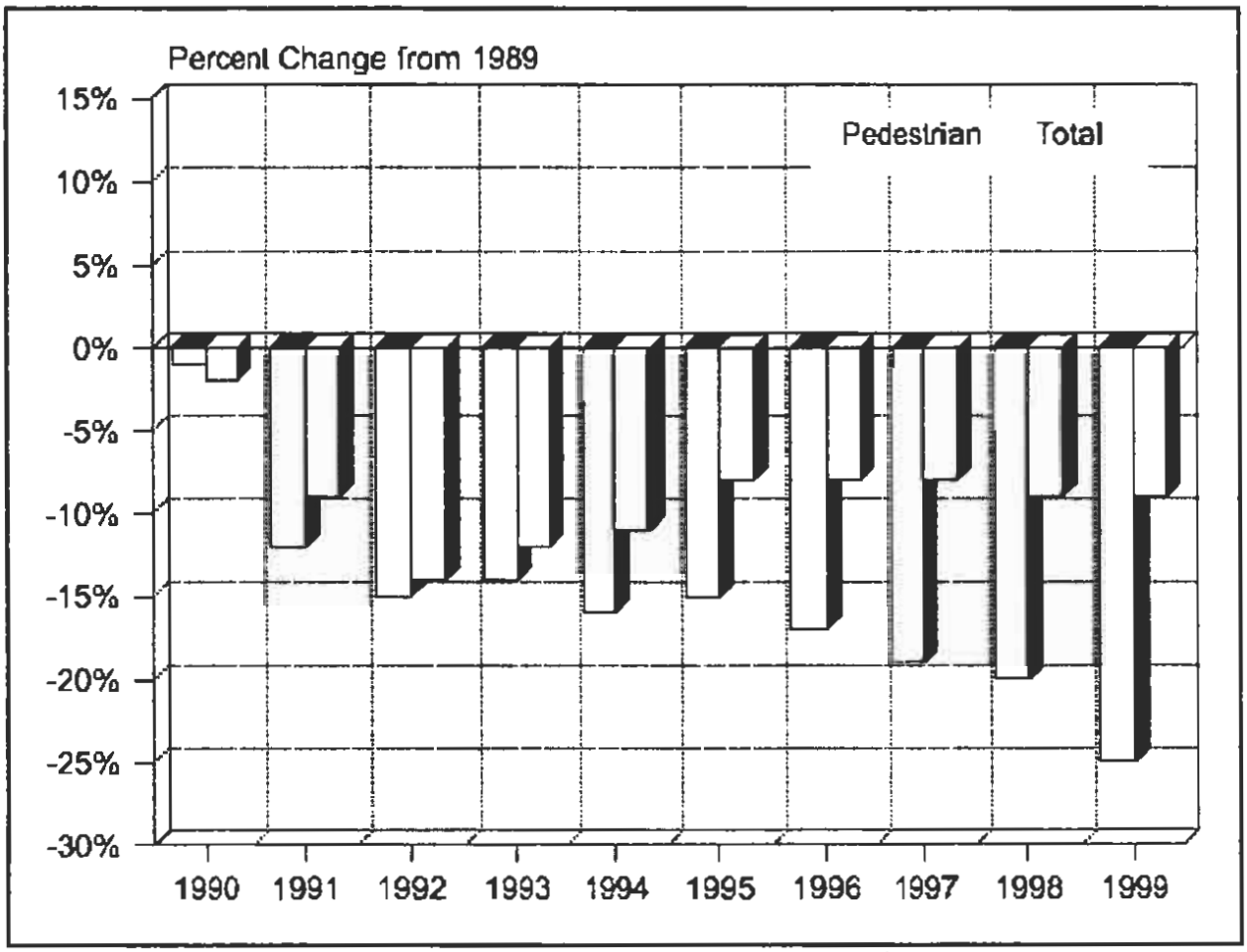
Highway System

Since the 1930's, the United States highway system has evolved into the best in the world. The primary mission of this highway system was the safe, efficient and rapid movement of motor vehicles. Consequently, pedestrian travel within the highway right of way was not encouraged and often prohibited due to safety considerations. In 1938, the State of California initiated an aggressive highway development program which resulted in the construction of one of the best state highway systems in the country. One of the reasons for the excellent highway system in California is the quality of the design, operations, and maintenance policies. In fact, California is known as a national leader in highway transportation innovation. The term freeway originated in California and applies to a fully controlled access highway that does not require tolls of vehicles using the facility. The collection of tolls was a common practice in other states until the initiation of the federal Interstate Program in 1956. The phrase "fully controlled access" means, among other things, that pedestrians are prohibited from the freeway right of way except to cross the freeway using grade-separated structures. On the state highways without access control the challenge has been, especially in urban and suburban areas, to provided reasonably safe pedestrian access. Given the considerable disadvantage of pedestrians when in conflict with motor vehicles, special attention is warranted to policies relating to the

treatment of pedestrians. Over time the highway environments changed. These changes included such items as demographics, adjacent land use activity, and culture. As changes occur, policies to deal with mobility and safety of pedestrians need to be established and implemented.

Pedestrian Safety Concerns

Safety of pedestrians was examined first at the national level and then for California. Data indicates that the national trend of pedestrian fatalities declined during the decade of the 1990's. Figure 1-1 illustrates this steady decline and suggests that the level of pedestrian safety is improving; however, this data does not reflect the amount of pedestrian travel. Despite this apparent reduction, data further reveals that in a recent year, 1998, there were 5,220 pedestrian fatalities and approximately 69,000 injuries. It is also interesting to note that 78 percent of the pedestrian related collisions occurred at non-intersections. This information has encouraged policy pronouncements by the federal government that are intended to encourage pedestrian safety on the state and local highways, streets, and roads.



SOURCE: National Center for Statistics and Analysis; *Traffic Safety Facts 1999—Pedestrians.* (*23*)

Figure 1-1: Trends of Both Total Traffic and Pedestrian Fatalities for the US

On California state highways, pedestrian related collision data, reported from the Traffic Accident Surveillance and Analysis System (TASAS), showed that approximately 81 percent involved injuries while 14 percent were fatal. In contrast, 30 percent all non-pedestrian collisions resulted in injuries and only 0.6 percent resulted in fatalities. This implies that pedestrians involved in collisions are about 2.7 times more likely to be injured than non-pedestrians and are approximately 23 times more likely to be killed. The data also suggest that non-pedestrians who are involved in collisions are about 14 times more likely to escape injury or death, based on collision data over the past ten years.

It is clear that pedestrian involved collisions are very severe. Another interesting conclusion can be drawn by looking at some demographic collision data from 1997 in California. This data shows that 782 pedestrian fatalities and 14, 988 pedestrian injuries occurred in California in 1997. From this collision data, our younger children (ages 0-14) fared the worst with 4666 (31%) injuries, even though they only compose 24% of the total California population. (*99*) Elderly individuals (age 55 and older) accounted for 290 (37%) of all pedestrian fatalities in the state, even though they only compose 18% of the total population. (*99*) It is clear that the children and elderly are over-represented in pedestrian-vehicle collision statistics; however, they are more likely to be pedestrians. These groups may possess deficiencies in mobility, sensory, or cognitive functions. While these groups are at the greatest risks of being involved in pedestrian related collisions, they are often restricted to walking as a primary form of transportation. Their daily activities depend on having a safe accessible walking route to locations such as schools, job sites, and stores.

Although only about one percent of traffic collisions on the state highway system in 1997 involved pedestrians, 21% of all fatalities involved pedestrians (SWITRS). It is appropriate for Caltrans to reassess statewide pedestrian safety policy.

Benefits of Walking

Aside from the safety issue, walking can be an effective alternative to automobile travel for short trips. Origins can be connected to destinations and multiple modes, including walking, can be linked together for trips of greater distances.

Increasing the use of walking as a transportation choice can help alleviate some of the congestion on roadways and decrease the need for the physical road space. Many environmental benefits would be associated with the need for less pavement. Walking is not directly dependent on fossil fuels, which makes it a desirable form of transportation from both an economic and environmental standpoint. Savings in fuel and the reduction of emissions are benefits. Recreation is also a reason people walk. Pleasant walkway environments will attract users for both utility and leisure.

Walking is a simple, yet beneficial, form of exercise with many associated health benefits. Regular walking has been linked to a decreased risk of developing heart disease, cancer, stokes, diabetes, and other diseases. Other health benefits of walking are stress reduction and weight control.

Federal Policy

In 1994 US DOT secretary Rodney E. Slater pronounced policy emphasizing bicycle and walking safety. The subsequent policy statement established by the US DOT in *Accommodating Bicycle and Pedestrian Travel: A Recommended Approach* shifts greater priority to providing facilities for non-motorized modes of travel. The policy states, "bicycling and walking facilities will be incorporated into all transportation projects unless exceptional circumstances exist." The policy statement defines "due consideration," as applicable to the needs of pedestrians and bicyclists as, "at a minimum, a presumption that bicyclists and pedestrians will be accommodated in the design of new and improved transportation facilities." (*97*)

In addition, public agencies and interest groups, "are striving to define the most appropriate way in which to accommodate the two modes [bicycle and pedestrian] within the overall transportation system so that those who walk or ride bicycles can safely, conveniently, and comfortably access every destination within a community." (*97*)

Many policy statements, design guides, and professional groups treat bicycles and pedestrians together. Both are forms of non-motorized transportation. Their operational requirements are very different as are the laws that govern behavior of travel in both modes. Actions to encourage travel and/or improve safety for one mode are not necessarily helpful to the other. This study focuses only on actions to improve pedestrian transportation. Bicycle transportation is very important but is not directly addressed herein.

California Policy

Concerns over pedestrian safety in California led to the establishment of the Pedestrian Safety Task Force (PSTF) by Caltrans. The PSTF consists of representatives from the Federal Highway Administration (FHWA), Caltrans' headquarters and district traffic engineering personnel, California Highway Patrol, California Department of Health and Social Services, California Department of Motor Vehicles, local and regional agencies, and affected citizen advocacy groups. The Task Force was formed to develop plans and programs aimed at improving pedestrian safety statewide. Data from the TASAS database (1990-1999) was obtained by the PSTF and was used to determine pedestrian collision characteristics and trends on the state's highway system. The data that was obtained over a ten-year period showed that the number of collisions in which pedestrians were involved accounted for only about one percent of the approximately 1.6 million traffic collisions reported on the state highways. However, during the same period the number of pedestrian involved collisions totaled 17 percent of fatal collisions and nearly three percent of the injury collisions. The PSTF established a goal of reducing pedestrian collisions by twenty percent statewide by the year 2018. (*1*)

An important product of this task force was an April 1999 report that recommended several activities. One of those activities was the development of this research project. It involved the consolidation of all the policies and practices that affect the movement of pedestrians within the right of way of the California's state highways. Another aspect of this project was a nationwide literature search of safe pedestrian practices applied by state and local governments. This literature search also included reports from the transportation profession and other formal research projects.

Furthermore, an evaluation of the policies and practices from the national literature search was desired that would lead to recommendations for Caltrans to consider.

To reiterate Caltrans' continued commitment to pedestrian safety, a recent (March 26, 2001) Caltrans deputy directive, *Accommodating Non-Motorized Travel* (*19*), supports the best practice concepts. The directive is from the recent US DOT policy statement which was discussed previously.

Research Goals and Objectives

The primary goal of this research project was to collect all pedestrian policies related to state highways and determine their adequacy under the present circumstances. Additionally the policies and practices of other state Departments of Transportation, several larger cities, and professional and research organizations were identified and studied.

In order to accomplish this effort in a timely manner four specific, measurable research objectives were identified and completed:

1. To collect and compile relevant Caltrans policies and practices which relate to pedestrian design, control, operations, and maintenance.
2. To conduct a national search of publications which deal with the pedestrian - highway interface.
3. To compare the findings of the literature search to current Caltrans practices.
4. To make recommendations regarding new practices that may be investigated or implemented.

Methodology and Scope

This project was comprised of four specific methodological components. The first was the collection of the needed relevant pedestrian materials from Caltrans manuals. Pedestrian practices and policies within the State of California were compiled and reviewed from the following eight sources:

- California Vehicle Code
- Highway Design Manual (Caltrans)
- Traffic Manual (Caltrans)
- Maintenance Manual (Caltrans)
- Construction Manual (Caltrans)
- Project Development Procedures (Caltrans)
- California Environmental Quality Act (CEQA)
- New (Year 2000) California Laws Regarding Pedestrians
- Streets and Highways Code, Chapter Eight

The second component of the methodology was an extensive and comprehensive review of national, state, and local literature. A national literature review was conducted with several international sources also being reviewed. In this process, all 50 state Department of Transportation (DOT) agencies were contacted. Copies of literature documenting all practices and policies relating to pedestrian accommodation were requested from the State DOT's.

The transportation agencies of the 50 largest cities in the United States also were contacted, and in addition, 12 Metropolitan Planning Organizations (MPO's)

were contacted. A similar request was made for literature regarding the accommodation of pedestrians from these two agency types. Federal documents and websites were consulted for pedestrian information and transportation journals were reviewed as well.

The next step was to conduct a comparative analysis between California's current practices and practices of other public agencies. This enabled possible changes in California's practices to be identified.

The fourth and final component was to determine which possible changes could be readily implemented by Caltrans and which will require formal evaluation before making recommendations to change current state policies. This report is the compilation of the results of each of these four study components.

2.0 CALIFORNIA STATUTES AND CALTRANS POLICIES AND PRACTICES AFFECTING BICYCLES AND PEDESTRIANS

INTRODUCTION

California strives to be a leader in highway transportation innovation including policies that accommodate pedestrians utilizing state highways. To support this goal, the California Department of Transportation (Caltrans) desired to collect and compile into a single document all of its policies and practices which relate to pedestrian transportation. This chapter is intended to be that document.

The scope of this chapter is simply collecting information regarding pedestrians from the following California sources:

- California Vehicle Code
- Highway Design Manual (Caltrans)
- Traffic Manual (Caltrans)
- Maintenance Manual (Caltrans)
- Construction Manual (Caltrans)
- Project Development Procedures (Caltrans)
- California Environmental Quality Act (CEQA)
- New California Laws Regarding Pedestrians

FACTORS AFFECTING PEDESTRIANS

There are many factors affecting pedestrian safety. A major contributing factor in the occurrence and severity of traffic collisions is the behavior of both motorists and pedestrians. Motorists and pedestrians who participate in risky behavior are more likely to be involved in traffic collisions. One example of risky behavior is alcohol and drug use. Nationally in 1998, 46 percent of the traffic accidents resulting in pedestrian fatalities involved alcohol consumption by either the driver or pedestrian. (*3*) Another startling national statistic: "More than one-third of all pedestrians 16 years of age or older killed in traffic crashes in 1998 were intoxicated." (*4*)

Other important considerations include social variables, nighttime exposure, age and disabled status. Social factors can greatly affect the behavior and numbers of pedestrians crossing or walking near a roadway. When pedestrians walk in groups the pace of their walk usually accommodates slower group members and the ability of the entire group to move quickly is restricted. Another important social factor is income; lower income Californians will more likely be pedestrians.

Pedestrians walking on or beside the roadway at night may be more subject to hazards because it is much more difficult for drivers to see pedestrians. Pedestrians also typically overestimate the distance at which they can be seen by a driver. (*2*)

Young school children and elderly (retirement age) are more likely to be pedestrians. Additionally, people with disabilities that prohibit them from driving vehicles are also more likely to be pedestrians.

Pedestrian facilities will indeed affect the behavior of pedestrians. These facilities include sidewalks, pedestrian crossings, roadway markings, signing, and signalization systems. The quality and characteristics of these facilities will affect how pedestrians respond to the facilities and how they will behave in the transportation system.

Law enforcement will also affect the behavior of pedestrians. Pedestrians will be more likely to submit to traffic control if the traffic control is legally enforced.

Public education is also an important factor in the behavior of pedestrians in the transportation system. As pedestrians become more informed about potential hazards, they will be more likely to be safer pedestrians.

Children

Children are a high-risk group of pedestrians because a child's conception and perception of traffic situations on roadways is not fully developed. For example, children have difficulty judging safe distance of an approaching car. Another factor that contributes to the child pedestrian problem is the diminutive stature of children, which makes it more difficult for drivers to see them. Many children at a young age believe that running to cross a street is the safest method. (*2*) Children also can have a poor understanding of the use of traffic control devices and crosswalks because of their lack of knowledge and experience.

Adolescents have a tendency to have a difficult time focusing their attention on obvious traffic hazards as their thoughts are on other matters. Adolescent pedestrian accidents are found to occur most commonly in or near residential areas and in areas where there is no traffic control.

Elderly

Elderly people tend to walk frequently for many reasons; they have free time, walking is a great source of exercise, and it is an inexpensive method of travel. Also, many elderly people can't, drive or chose not to drive. However, elderly pedestrians can be at risk because of factors such as limited vision, reduced ability to see at night, limited hearing, slower reaction time, and reduced walking speeds.

Disabled

Currently people with disabilities are much more mobile in our society than a few decades ago. The typical conception of a disabled person is someone in a wheelchair; however, there are many different varieties and levels of disabilities. Vision and hearing deficits can cause significant problems when it comes to the detection of traffic hazards. Other disabilities include difficulties associated with balance, stamina, maneuverability, and reaction time. People who must use canes or crutches to assist them in walking illustrate still another type of disability. Limitations can also include mental disabilities as well as physical disabilities. Pedestrians who are illiterate, dyslexic, or have brain damage may have difficulties understanding traffic conditions and comprehending dangers. Many of these disabilities can pose a severe safety risk.

FACILITIES

This portion of the paper discusses the major facilities that are used by pedestrian traffic. Each section of this portion of the paper will discuss the importance of the facility to pedestrian traffic and how the facility is used by pedestrians.

General

School Zone

Pedestrian-involved traffic collisions are a significant concern, and this issue is of great concern in areas where the pedestrians are school age children. There are many alternatives and considerations that must be evaluated when developing a school crossing. (*7*) These are as follows:

- Warning sign and markings.
- Variable Speed Limits.
- Intersection stop signs.
- Flashing yellow beacons.
- Traffic signals.
- Removal of visibility obstructions.
- School safety patrol.
- Adult crossing guard.
- Pedestrian separation structures.
- Pedestrian walkways along the roadway.
- Pedestrian walkways separated from the roadway.
- Parking controls and curb-use zones.
- Bus transportation.

Traffic signals are fundamental to the assignment of right-of-way and directing traffic at intersections. In the process of designing school crossing signals, the following applies (*7*):

- "Pedestrian signal faces of the International Symbol type shall be installed at all marked crosswalks and at signalized intersections along the route."
- "Non-intersection school pedestrian crosswalk locations may be signalized when justified."
- "If an intersection is signalized under this guideline for school pedestrians, the entire intersection shall be signalized."
- "School area traffic signals shall be traffic actuated type with push buttons or other detectors for pedestrians."

Where children walk along the roadway, shoulders at least 1.8m (5.9ft) wide on both sides of the traveled way are desirable. Where a walkway is provided, at least 1.2m (3.9ft) wide and physically separated from the travel way, the walkway may be limited to one side of the roadway. (*7*)

Pedestrian markings and crosswalks in a roadway near school grounds shall be painted or marked in yellow. At intersections all pedestrian crosswalks must be marked in yellow if yellow marking is required on one of the crosswalks.

Other marked pedestrian crosswalks may be painted or marked in yellow if either the nearest point of the crosswalk is not more than 182.8 m (600 ft) from a school building or school grounds or if all of the following conditions are met:

- The nearest point of the crosswalk is not more than 853.4 m (2800 ft) from a school building;
- There are no intervening crosswalks other than those next to the school grounds; and
- It appears that the facts and circumstances require special painting or marking of the crosswalks for the protection and safety of persons attending the school. (*5*)

The words "SLOW--SCHOOL XING" shall be painted or marked in yellow on each side of the street, in the lane or lanes leading to all yellow marked crosswalks. The words shall not be painted or marked in any lane leading to a crosswalk at an intersection controlled by stop signs, traffic signals, or yield right-of-way signs.

A crosswalk shall not be painted or marked yellow at any location other than as required or permitted in this section. (*5-21368*)

Highway Capacity

Design capacity of highway facilities is very important to the design process. It helps determine the quality of travel motorist will experience. One of the design capacity variables is pedestrian traffic, which can adversely affect vehicle highway capacity. Pedestrian signalization at intersections increase the minimum green time, which reduces motor vehicle efficiency. Also pedestrian activity at intersections can negatively affect turning vehicles during a green phase. (*6*)

Parking

Parked vehicles may restrict visibility between pedestrian and vehicular traffic; therefore, parking controls may be needed to improve pedestrian safety. (*7*)

Major Highways

Freeways

The Department of Transportation has the right to prohibit the use of freeways by pedestrian traffic. An exception to this rule is in the specific case when a vehicle has been incapacitated; the driver of the vehicle may walk to the nearest exit, on the same side of the freeway in which the vehicle is disabled. (*5-21960*)

"Section 21960 of the Vehicle Code authorizes the Department of Transportation and local authorities, with respect to freeways under their respective jurisdictions, to prohibit or restrict the use of freeways by pedestrians, bicyclists or other non-motorized traffic or by any person operating a motor-driven cycle or a motorized bicycle." (*7*)

Caltrans is allowed to prohibit non-motorized traffic on freeways according to Section 21960 of the CVC, and it is Caltrans' policy to disallow pedestrian traffic on freeways.

Expressways and Conventional Highways

In the area of expressways and conventional highways pedestrian traffic is allowed; however, when pedestrians are walking on roadways other than in business or residential areas, the pedestrian should use the left-hand edge of the roadway for their path of travel. (*5-21956*)

Toll Bridges

When contemplating the construction of new toll bridges, pedestrian facilities should be considered in the design process in order to secure the flow of non-motorized traffic in the area. (*9*)

Median Fences

The purpose of fences as they pertain to pedestrians is that "...median fences are often constructed to help prevent indiscriminate crossings of the median by vehicles or pedestrians." (*6*)

Highway Bridges

A pedestrian may be ordered off a bridge or overpass structure if a law officer has grounds to believe that the pedestrian is disrupting traffic or violating the law. (*5-21962*) "Bridge sidewalks should be provided where justified by pedestrian traffic." (*6*)

The class of bridge railings that pertains to pedestrian traffic is called pedestrian railing. The purpose of this railing is to prevent pedestrians from falling from the structure accidentally. Fence-type railing is used on overpasses to reduce the risk of pedestrians dropping objects on the roadway below. In areas where the facility is accessible to disabled persons, a handrail must be provided. There are specific railings that are to be used when pedestrian traffic is permitted on bridge structures.

Intersections

Between Intersections

"Between adjacent intersections controlled by traffic control signal devices or by police officers, pedestrians shall not cross the roadway at any place except in a crosswalk." (*5-21955*)

Intersections at Grade

At grade intersections may be equipped to handle a variety of conflicts involving vehicles, pedestrians, and bicycles. Pedestrians may be accommodated at intersections with the use of marked and unmarked crosswalks, safety islands, or raised safety islands as determined by design analysis. (*6*)

Urban Facilities

Sidewalks and Curbs

"The driver of any motor vehicle, prior to driving over or upon any sidewalk, shall yield the right-of-way to any pedestrian approaching thereon." (*5-21952*)

Regarding pedestrian facilities, sidewalks are a major concern. Sidewalks are paved pathways for pedestrian usage and are usually located to the side of a highway, road, or street. The state may assume financial responsibility for the construction of sidewalks under the conditions described below.

- Replacing current sidewalks disturbed by state highway construction (replacement in kind). Also, the state may assume financial responsibility to fill in sidewalk gaps within project area.
- Contributing to the cost if traffic safety or capacity will be increased on conventional state highway when city, county, or property owners whose development generated the pedestrian traffic build sidewalks on state right of way under permit.
- Building sidewalks across the freeway right of way on bridges or through under-crossings to connect existing or planned sidewalks.
- Widening the fill to provide for future sidewalks planned on over-crossing structures that are not now warranted.
- Providing school pedestrian walkways when all of the following conditions are met:
  - The highway coincides with "Suggested Route to School"; and
  - The existing road shoulders that lie outside the traveled way are less than 2 m (6.6 ft) wide; and
  - More than 20 children per day use the route walking to or from school, and vehicular travel exceeds 100 vehicles per hour during those periods of the day; and
  - The governing school board district officially requests the pedestrian walkway improvements; and
  - Revision of the "Suggested Route to School" or the attendance boundaries to eliminate the condition is impractical.
- Connecting local streets by building sidewalks along frontage roads that would otherwise dead end at the freeway provided the intersecting streets have sidewalks.
- Building sidewalks on separated cross streets where re-construction of the cross street is made necessary by the freeway project and it is necessary to connect existing or planned sidewalks.
- Constructing sidewalks to connect local streets to bus stops.

The responsibility for the maintenance of sidewalks within the right of way rests with the State. Exceptions to this responsibility include places where the sidewalk was placed by a private party under an encroachment permit. Another exception is where the "...city or county has placed non-standard sidewalks with colored or textured surfaces, or meandering alignment." (*6*)

Sidewalks should be periodically inspected for holes, breaks, adjacent slab height variations, and other damage. Curbs attached to sidewalks should be maintained to the same level as the sidewalk. Necessary repairs should be made promptly.

"Bridge sidewalks should be provided where justified by pedestrian traffic." (*6*)

The state shall resume responsibility for the repairs with the exception of the following cases:

- Placement of sidewalk by permit under encroachment permit.
- Maintenance agreement exists with city.
- Nonstandard items were requested by local agencies.

Local authorities may regulate, by ordinance, the parking and operation of bicycle and/or motorized scooter on pedestrian facilities if not in conflict with the *CVC*.
(*5-21225& 21206*)

For information regarding widths for sidewalk facilities on bridges, please refer to Figure 208.10 A and B in the Caltrans Highway Design Manual. (*6*)

Curbs and Gutters

Where necessary for the safety and protection of pedestrians, curbs may be provided at the ramp connection with a local street. (*6*)

Convenience to pedestrian traffic is one of the major variables of good roadway drainage design. In roadway drainage the water spread on urban streets should be minimized where a large number of pedestrians use the adjacent sidewalks and pedestrian crosswalks.

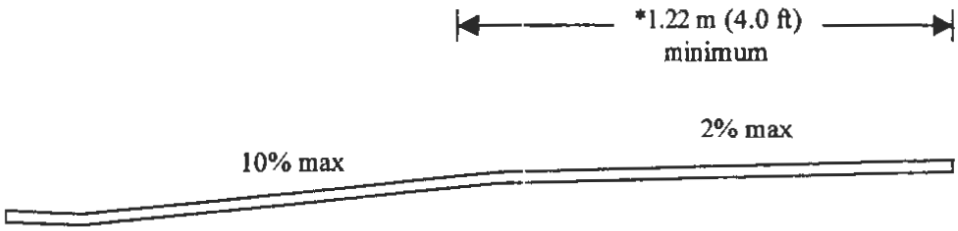
Often curbs and gutters are constructed for pedestrian traffic. If pedestrian traffic is a controlling factor in curbed intersections, intersection drainage presents the following alternatives to be weighed as to effectiveness and economy.

- Intercept the whole flow upstream of the crosswalk.
- Intercept a part of the water and allow the overflow to cross the intersection. The width of flow should be controlled so that pedestrian traffic is not excessively restricted.
- If flow is small, pass the entire flow across the intersecting street in a valley gutter.

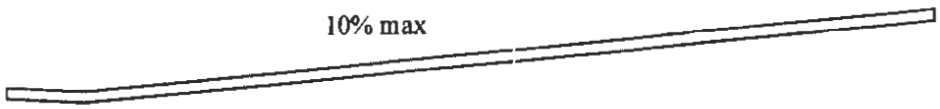
The location of grate inlets should be avoided within pedestrian walkways. The typical inlet location for streets or road crossings is at the upstream end of the curb or pavement return and clear of the pedestrian crosswalk. (*6*)

Urban Driveways

In areas where sidewalks cross-driveways, "...accessibility regulations require that a relatively level (2% maximum cross fall) path, at least 1.22 m (4 ft) wide, is provided." (*6*) In areas where pedestrian activity is not present and is not expected to be present in the reasonable future, it is possible for the designer to develop a driveway that eliminates the flatter portion along the back edge of the driveway instead of the use of the Standard Plans for driveways. Figure 2-1 is a diagram of driveway cross-sections from Caltrans Standard Plans.



Normal driveway passing through sidewalk.



Driveway passing through sidewalk where no pedestrian traffic is expected.

*Clear width may be reduced to 915 mm (3.0 ft) where right of way restrictions, natural barriers, or other unreasonable hardships exist.

Source: Standard Plans July 1997, Caltrans

Figure 2-1 Driveway Profile

Bikeways

In areas that provide pedestrian facilities for pedestrian traffic, no pedestrian shall use bicycle lanes as a pathway for travel. (*5-21966*)

Class I bikeways (bike paths) serve " ...the exclusive use of bicycles and pedestrians." (*6*) "Class I bikeways (bike paths) are facilities with exclusive right of way, with cross flows by motorists minimized." (*6*) If significant use by pedestrian traffic is anticipated then separate facilities should be constructed. "Dual use by pedestrians and bicycles is undesirable, and the two should be separated whenever possible." (*6*) Sidewalks are not considered to be Class I facilities because there are primarily used by pedestrian traffic. In areas where heavy bicycle traffic and pedestrian traffic is predicted, the pathway should be preferably 3.6 m (11.8 ft) wide or more. Intersection crossings for the Class I bikeway should, "...occur at the pedestrian crossing, where motorists can be expected to stop." (*6*)

Class II bikeways (bike lanes) are one-way, striped lane facilities for preferential use of bicycles. Vehicles may enter the bike lane to make a right turn, where permitted, 30m (98.4ft) to 60m (196.9ft) before an intersection, as marked by a dashed line. The manual makes no mention of pedestrian use of bicycle lanes.

Class III bikeways (bike routes) are bicycle facilities that are either shared on the roadway with motor vehicles or with pedestrians on sidewalks. The purpose of this type of bikeway is to connect discontinuous bicycle facilities. Bicycle use is secondary to vehicular use on streets and pedestrian use on sidewalks.

Traffic Islands

"A traffic island is an area between traffic lanes for control of vehicle movements or for pedestrian refuge." (*6*) Traffic islands can be used to protect and aid pedestrians crossing a roadway.

"Raised medians or islands in street crossing paths shall be either cut through level with the street or have curb ramps and a level area at least 1.2 m long between curb ramps." (*18*) A detectable warning surface with at least a 600mm (2.0ft) width is required at cut through locations because vision impaired pedestrians will be adjacent to traffic without the protection a raised barrier offers.

Pedestrian Crossings

Pedestrian Crossings

A driver of a vehicle must yield to pedestrian traffic in both marked and unmarked crosswalks at an intersection. An unmarked crosswalk is "...the prolongation or connection of the boundary lines of sidewalks at intersections where the intersecting roadways meet at approximately right angles, except of prolongation of such lines from an alley across a street." (*5-21950*)

Even though vehicles must yield to pedestrian traffic, it does not relieve pedestrians of their responsibility for safety on roadways. "No pedestrian may suddenly leave a curb or other place of safety and walk or run into the path of a vehicle which is so close as to constitute an immediate hazard." (*5-21950*) Pedestrians should use due care to preserve his or her safety. (*5-21950*)

The above provision "does not relieve a driver of a vehicle from the duty of exercising due care for the safety of any pedestrian" within any marked or unmarked crosswalk. (*5-21950*)

The driver or a vehicle shall exercise "due care" and shall reduce the speed of the vehicle or take any other action to safeguard the safety of a pedestrian who is in any marked or unmarked crosswalk. (*5-21950*)

In areas where pedestrian traffic is crossing a roadway by means other than a pedestrian tunnel or overhead crossing, if one of these facilities serves the area, the pedestrian shall yield to all oncoming traffic so as to avoid a hazardous situation.

When walking on roadways other than in business or residential areas, the pedestrian should use the left-hand edge of the roadway for their path of travel.

"Pedestrian crosswalk markings may be placed at intersections, representing extension of sidewalk lines, or on that portion of the roadway distinctly indicated for pedestrian crossing." (*8*) Crosswalks should be placed discriminately because a pedestrian may experience a false sense of security in crosswalks. The purpose of a marked crosswalk is to direct the pedestrian to a suitable path. (*7*)

In situations where a vehicle has stopped at a marked or unmarked crosswalk allowing for pedestrian traffic to cross the roadway, drivers of other vehicles approaching from the rear are not permitted to pass the stopped vehicle. (*5-21951*)

Pedestrian Grade Separation

The need for the construction of pedestrian grade separations is based on a study of a particular area or community's present and future needs. This study

encompasses sources that produce pedestrian traffic in the particular area. Considerations include volumes of pedestrian crossing traffic, the type of highways being crossed, the location of the crossing facilities, cultural factors, sociological factors, and the prevailing age and type of people using the facility. (*6*)

The state should pay the full cost of the pedestrian grade separations when it has been justified prior to approval of highway construction contract. When pedestrian grade separations are approved after a highway construction contract, the State's share of the separation construction should not exceed 50% of the cost. (*6*)

On conventional highways grade separations are not usually provided for pedestrians. Where pedestrian use is substantial and also if it has been requested by local agencies that there should be construction of a pedestrian separation, an over-crossing may be considered. Pedestrian traffic should be provided adequate walkways in areas of over-crossings and under-crossings. (*6*)

Handrails are required on ramps with a rise greater than 150mm (6in) or a horizontal projection longer than 1830mm (6ft). (*18*) The following requirements pertain to handrails: (*18*)

- Provide handrails for both sides of ramps and the inside rail must be continuous for switchback paths.
- Extend the handrail parallel to the ground at least 305mm (1 ft) past the ramp.
- Limit clear space between the handrail and the wall to 38mm (0.125in).
- Provide a continuous gripping surface.
- Mount the gripping surface between 865mm (34in) and 965mm (38in) above the ramp.
- Round the ends of handrails or return them smoothly to the floor.
- Restrain handrails from turning in their fittings.
- Provide a grip portion to the handrail that is not less than 32mm (1.25in) or greater than 38mm (1.5in) or a shape that will provide an equivalent grip.
- Eliminate any sharp corners on gripping surfaces.

Ramps that are longer than 3m (10ft) and are not confined by a wall or fence require a guard. Either a 50mm (2in) guide curb on each side of the ramp or wheel guide rail located at 76mm (3in) plus or minus 25mm (1in) above the ramp surface shall be used. (*18*)

Ramps must possess a landing at both the top and bottom locations. The design of the landings must conform to the following requirements (*18*):

- The landing width must be at least as wide as the ramp or 1.5m (5ft); whichever is greater.
- The landing area must be at least 1.5m (5ft) by 1.5 (5ft) if the ramp changes directions at the landing.
- The landing length at the bottom of a ramp must be at least 1.8m (6ft).
- The landing length must be at least 1.8m (6ft) at the bottom or intermediate location on a ramp if the direction of the ramp changes more than 30 degrees.

Curb ramps with a slope less than 1:15 (6.67%) require a detectable warning surface. Detectable warning surfaces must be 600mm wide and consist of raised truncated domes. (*18*)

Grooves, consisting of 6mm indentations separated by 20mm on center, must be located at the top of a curb ramp. "Grooves shall form a 300mm (1ft) border at the level surface of the sidewalk" (*18*)

The engineer that is overseeing a project involving a pedestrian facility has the responsibility of ensuring that the plans and specifications correspond to the policies specified in the Caltrans Highway Design Manual. (*6*)

Hitchhiking

"No person shall stand in a roadway for the purpose of soliciting a ride from the driver of any vehicle."(*5-21597*)

Skiing or Tobogganing (21959)

It is against the law for a person to cross a roadway on skis or toboggan in such a way that it will obstruct vehicular traffic. A person on skis or toboggan is considered a pedestrian and must abide by pedestrian rules of the roadway. (*5-21959*)

Disabled Pedestrians

No person shall carry a white cane if they are not totally or partially blind. A visually disabled person who is carrying a white cane or using a guide dog shall have the right-of-way. Any driver of a vehicle that fails to yield or take the necessary precautions to avoid injury for a visually disabled person is guilty of a misdemeanor. (*5-21963,4*)

Wheelchair access should be provided to pedestrian grade separation structures. Wheelchair ramps and/or curb openings should also be provided in areas of mid-block crosswalks and in areas where pedestrians cross-curbed channelization or median islands at intersections.

"Section 4450 of the California Government Code requires that buildings, structures, sidewalks, curbs, and related facilities that are constructed using any State funds, or the funds of cities, counties, or other political subdivisions be accessible to and usable by the physically disabled." (*6*)

The Federal Americans with Disabilities Act (ADA) of 1990 states that in the area of pedestrian traffic, the disabled community needs to be involved in the development of pedestrian facilities such as sidewalks, ramps, street crossings, parking facilities, and transit access facilities.

Non-motorized Transportation Facilities

Non-motorized Transportation Facilities

A non-motorized transportation facility is defined as "a facility designed primarily for the use of pedestrians, bicyclists, or equestrians. It may be designed for one of these uses or it may be designed as a joint-use facility. A non-motorized transportation facility may be part of the highway or it may be separated from highway traffic for exclusive use." (*9*)

The development of non-motorized transportation facilities usually falls into one of the following categories (*9*):

- "Replacement of a non-motorized existing route for non-motorized traffic that is being severed or destroyed by freeway construction." (*10*)
- "Provision of a non-motorized facility along a new freeway corridor where non-motorized facilities do not exist." (*10*)
- "Provision of a non-motorized facility along a State highway under a Cooperative Agreement at the request of a local agency." (*10*)
- "Provision of a non-motorized facility along a State highway based upon a finding that the traffic safety or capacity of the highway will be increased." (*10*)

In conjunction with the State Highway System there is a minimum requirement that at least $360,000.00 be used on the development of facilities for non-motorized traffic. This is stated in section 888.4 of the Streets and Highways Code (S&H Code).

Project reports must be prepared for projects for non-motorized transportation facilities that are either within the state right of way or are in conjunction with a State construction project. The design portion of projects must take into consideration the requirements of non-motorized transportation users. The design and planning portion of a project must also correspond with the federal, State, regional, and local agencies' regulations.

Parallel Facilities

"Section 887.8 of the S&H Code states that Caltrans may construct and maintain non-motorized transportation facilities approximately paralleling State highways after consulting with the law enforcement agency having jurisdiction over the highway." (*9*)

If it is determined that a non-motorized transportation facility that is approximately paralleling the highway would increase traffic capacity or safety then Caltrans will fund both the construction and maintenance of the facility.

Deputy Directive 64

Caltrans recently issued a Deputy Directive that was effective on March 26, 2001. This Directive is entitled *Accommodating Non-Motorized Travel*, and has a policy statement that includes the following: "The Department fully considers the needs of non-motorized travelers (including pedestrians, bicyclists and persons with disabilities) in all programming, planning, maintenance, construction, operations, and project development activities and products." In addition, the Directive states, "the Department adopts the best practice concepts in the US DOT Policy Statement on Integrating Bicycling and Walking into Transportation Infrastructure." (*19*)

CONTROL MEASURES

Warning signs, regulatory signs, markings, and signals will be discussed in this portion of the paper. Each section will describe how each of the topics are related to pedestrian traffic and how they are used by pedestrians. In general pedestrians do have a responsibility to obey control measures. "It shall be unlawful for any

pedestrian to fail to obey any sign or signal erected or maintained to indicate or carry out the provisions of this code (*CVC*) or any local traffic ordinance or resolution adopted pursuant to a local traffic ordinance, or to fail to obey any device erected or maintained..." (*21461.5*)

Signing

Warning Signs

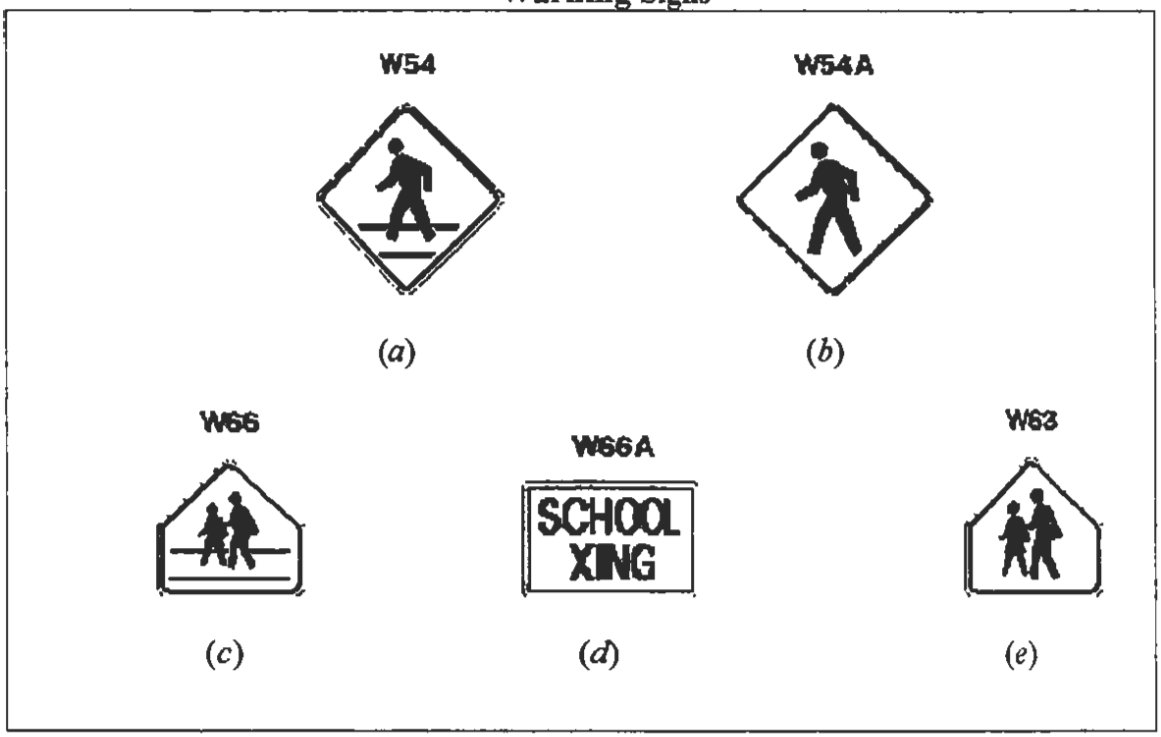
"Warning signs are used to guide and warn of traffic conditions on or adjacent to a highway or street." (*7*) The Pedestrian Crossing symbol sign (W54-Fig. 2-2-*a*) is used in areas of marked crosswalks. These areas are generally areas where entry into the roadway by pedestrians is not apparent to the motorist. This sign is not to be used at crossings that are controlled by a stop sign or traffic signal. This sign should be located adjacent to the crossing or up to 15 m (49.2 ft) in advance of the crossing.

The Pedestrian Symbol sign (W54A-Fig. 2-2-*b*) may be used in advance of a crosswalk or crossing area and also in advance of the Pedestrian Crossing sign (W54).

The Advance School Symbol sign (W63-Fig. 2-2-*c*) may be used in advance of remote school crosswalks in areas outside of the school zone.

The School Crossing Symbol sign (W66-Fig. 2-2-*d*) is usually combined with the School Xing plate (W66A-Fig. 2-2-*e*). This combination of signs shall not be used in areas that are controlled by a yield sign, stop sign, or traffic signal.

Warning Signs



Source: Caltrans

Figure 2-2 Pedestrian Related Warning Signs

Regulatory Signs

The purpose of regulatory signs is to inform highway traffic, including pedestrians, of regulations and laws.

The Pedestrians Prohibited sign (R43-Fig. 2-3-*a*) shall be used at all freeway exit ramps to inform pedestrians that they are not allowed in this area.

The Pedestrians, Bicycles, Motor-Driven Cycles Prohibited sign (R44-Fig. 2-3-*b*) shall be used on freeways to inform the person or persons that these modes of transportation are not allowed in this area.

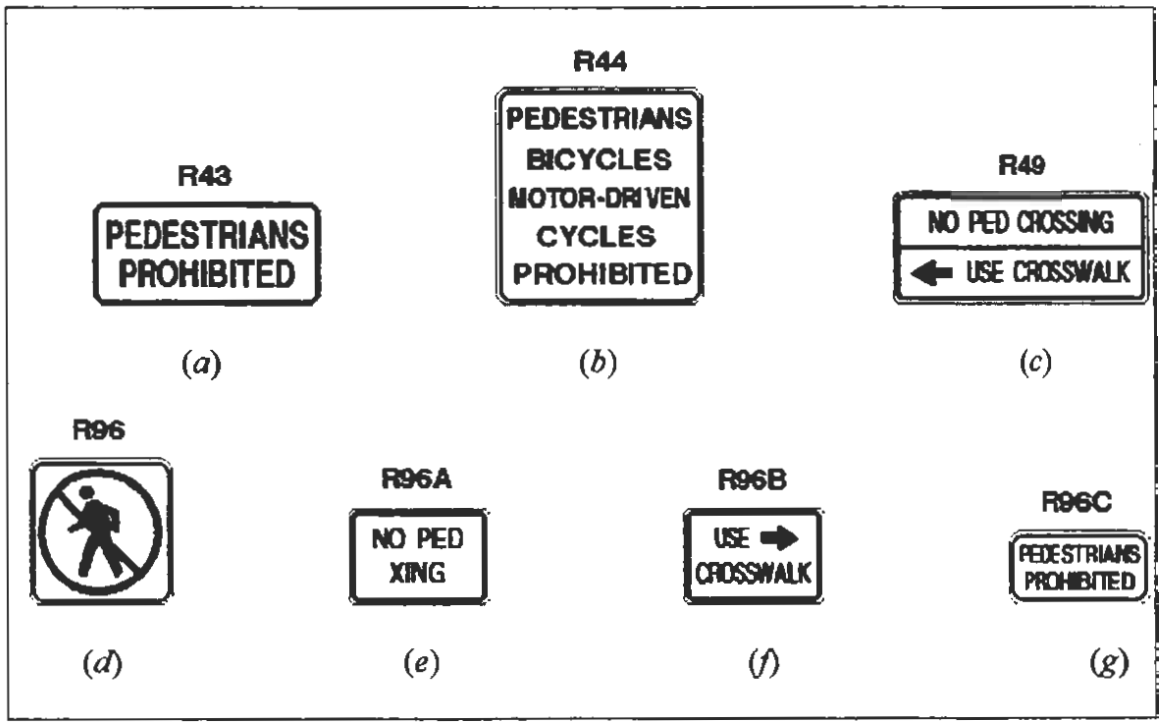
The No Ped Crossing - Use Crosswalk sign (R49-Fig. 2-3-*c*) should be used in areas to inform pedestrians not to cross the roadway and to instruct them where the nearest crosswalk is located.

The No Pedestrian Symbol sign (R96-Fig. 2-3-*d*) should be used in areas where pedestrians are prohibited.

The No Pedestrian Crossing sign (R96A-Fig. 2-3-*e*) may be used below the R96 sign in areas where pedestrian traffic is prohibited from crossing.

The Use Crosswalk sign (R96B-Fig. 2-3-*f*) should be used to help inform pedestrians that they are to use the designated crosswalk to cross the roadway.

The Pedestrians Prohibited sign (R96C-Fig. 2-3-*g*) shall be used in areas where pedestrian traffic is prohibited.



Source: Caltrans

Figure 2-3 Pedestrian Related Regulatory Signs

Markings

Diagonal markings should be used in areas where it is a necessity to emphasize or discourage vehicular traffic. An area where this is a consideration is in pedestrian refuge island areas.

"An island is a defined area between traffic lanes for control of vehicle movement or for pedestrian refuge." (*7*)

Crosswalk markings for pedestrian traffic should be placed in areas designated for pedestrian crossing. The primary purpose of pedestrian crosswalk markings is to guide pedestrians to a preferred path. There are many factors that must be considered when determining the placement of a crosswalk. (*7*) These factors include:

- Vehicular approach speeds from both directions.
- Vehicular volume and density.
- Vehicular turning movements.
- Pedestrian volumes.
- Roadway width.
- Day and night visibility by both pedestrians and motorists.
- Channelization as desirable to clarify pedestrian routes for sighted or sight impaired pedestrians.
- Discouragement of pedestrian use of undesirable routes.
- Consistency with markings at adjacent intersections or within the same intersection.

The usage of mid-block pedestrian crossings is discouraged because they are usually unanticipated by drivers of vehicles. In areas where roadways contain two or more traffic lanes, cautious use of mid-block crossings is in order because a vehicle can conceal pedestrian traffic.

The markings used to designate a crosswalk are two solid lines that mark the edges of the crosswalk. When crosswalks markings are used the width of the solid lines should be no less than 300 mm (11.8 in). Limit lines stretch across all the approach lanes at an intersection and are used to instruct vehicles as to where to stop. (*7*)

Traffic Signals

Pedestrians may enter a marked or unmarked crosswalk when facing a circular green signal unless otherwise directed by a pedestrian control signal or prohibited by a posted sign. The pedestrian must yield the right of way to vehicular traffic lawfully in the intersection at the time the signal was first shown. (*5-21451*)

A pedestrian shall not enter the roadway when facing a steady yellow or red circular or arrow signal, unless otherwise directed by a pedestrian control signal. (*5-21452*)

A pedestrian may enter the roadway when facing a pedestrian control signal displaying "WALK" or the approved "Walking Person" symbol. The pedestrian must yield the right of way to vehicular traffic lawfully in the intersection at the time the signal was first shown. (*5-21456*)

No pedestrian shall begin to cross a roadway when facing a pedestrian control signal, either flashing or steady, displaying "DON'T WALK," "WAIT," or the approved "Upraised Hand" symbol. (*5-21456*) However, pedestrians are to continue their crossing movement, when safe, in the crosswalk when the pedestrian control begins to flash.

Traffic control devices are used to control vehicle and pedestrian traffic by assigning right of way. Traffic control signals aid pedestrian traffic to cross major streets.

There are eleven warrants stated in the *Traffic Manual* that justify considering the installation of traffic signals. The third warrant pertains to pedestrian traffic volumes. It states that where the pedestrian volume crossing the street is "...100 or more for each of any four hours; or 190 or more during any one hour..." the installation of a traffic signal to serve pedestrians may be warranted. (*7*) These volumes may be reduced up to 50 % when the prevailing pedestrian traffic crossing the roadway is crossing at a speed below 1 m/s (3.3 ft/s).

The decision to install a traffic signal may not be based solely on this or any other warrant. It first must be demonstrated that a stop sign would be inadequate for the location in question. Careful consideration must be taken because of the increase of some types of collisions with the introduction of a traffic signal. The pedestrian counts should encompass the duration of the average day when the most traffic is present and traffic signals would be needed most. The traffic counts should be a minimum of 8 hours total and include both A.M. and P.M. peak hours.

It is more efficient to use pedestrian signal faces rather than vehicular signal faces. Pedestrian signal faces that are used with appropriate timing provide for a safer crossing environment. When new signal faces are being installed the signal used should be the international symbol, the WALKING PERSON and the upraised HAND. The older pedestrian signal faces with the "WALK-WAIT" signal faces may still be used. Pedestrian push buttons should be used and located at a convenient position for pedestrian traffic. (*7*)

"The total pedestrian crossing time shall consist of the walk interval plus the pedestrian clearance time obtained by using a walking rate of 1.2 m/s (3.9 ft/s). Under normal conditions, the walk interval should be at least 4 seconds in length."(*7*)

An audible pedestrian signal supplements the typical pedestrian signal faces. The installation of this device requires an engineering study and evaluation and all of the following minimum conditions must be met:

- The proposed intersection crosswalk must be signalized.
- The audible devices should be retrofittable to the existing traffic signal hardware.
- The signalized intersection should be equipped with pedestrian push buttons.
- The selected crosswalk must be suitable for the installation of audible signals, in terms of surrounding land use and traffic patterns.
- There must be a demonstrated need for the audible signals in the form of a request from an individual or group that would use the audible signal.
- The individual or group requesting the device should agree to train the visually impaired users of the audible signals.

The recommendation of use for audible pedestrian crossing devices states that the devices should emit a "Cuckoo" sound to correspond with the "WALK" indication for crosswalks in the North-South direction and a "Peep-Peep" sound with the "WALK" indication for crosswalks in the East-West direction. (*7*)

CONSTRUCTION, OPERATIONS, AND MAINTENANCE

Construction, operations and maintenance are very important components to any pedestrian facility. In order for these facilities to be used properly and safely they must be properly constructed, operated and maintained to ensure pedestrian safety and mobility. This section focuses on the construction, operation and maintenance of pedestrian facilities.

Construction

The need for the construction of pedestrian grade separations is based on a study of a particular area or community's present and future needs. This study should encompass sources that produce pedestrian traffic in the particular area. Considerations should include volumes of pedestrian crossing traffic, the type of highways being crossed, the location of the crossing facilities, cultural factors, sociological factors, and the prevailing age and type of people using the facility. (*6*)

The state should pay the full cost of the pedestrian grade separations when it has been justified prior to approval of highway construction contract. When pedestrian grade separations are approved after a highway construction contract, the state's share of the separation construction should not exceed 50% of the cost. (*7*)

On conventional highways grade separations are not usually provided for pedestrians. Where pedestrian use is substantial and an over-crossing has been requested by a local agency, an over-crossing may be considered. Pedestrian traffic should be provided with adequate walkways in areas of over-crossings and under-crossings. The engineer that is overseeing a project involving a pedestrian facility has the responsibility of ensuring that the plans and specifications correspond to the policies specified in the Caltrans Highway Design Manual. (*7*)

It is stated in Section 888.2 of the S&H Code that Caltrans will incorporate facilities for non-motorized transportation into the design of freeways included into the State Highway System in areas where non-motorized traffic facilities do not exist. These facilities are financed by the State Highway funds.

It must be determined by the project engineer during a new construction project whether a non-motorized transportation facility or alternate route exists or is intended. These results must be discussed in a regular project hearing for the project. For projects that are past the regular project hearing stage, the local agencies must be contacted and the results of the project discussed. At the public hearing, the project and the non-motorized facilities need to be discussed and documented properly. The non-motorized transportation facilities are to be financed with the state highway funds. (*9*)

Traffic Control Plans

Consideration for pedestrians must be included in plans for moving traffic through a construction zone.

Pertaining to pedestrians, "...the traffic control plans should be consistent with Chapter 5 of the *Traffic Manual*, *Manual of Traffic Controls*, and the philosophies and requirements contained in standard lane closure plans developed by the Headquarters Traffic Operations Program for use on State highways and should cover, as

appropriate, such items as: ...consideration for bicycle and pedestrian traffic." (*6*) Traffic control in work zones is discussed in the next section.

Traffic Controls In Work Zones

Maintenance, construction and utility work should be planned and conducted with the pedestrian in mind. Traffic control zone plans should naturally be developed to provide for pedestrian safety. The *Highway Design Manual* references the following policies for traffic control plans, as stated in the previous section of this paper. (*7*)

In traffic control work zones pedestrians should be guided to and provided with an adequate and safe route through or around the work zone in question. In particular pedestrian paths should be developed to minimize pedestrian exposure to wayward vehicles. These paths should be easily traversed and not possess any abrupt changes in grade or terrain. Cut zones through pedestrian walkways should be minimized because abrupt grade changes and muddy surfaces often accompany them. (*7*)

Pedestrians should be given advance warning of temporary traffic control zones. Signs should be posted at intersections to direct necessary crossing to eliminate the need for mid-block crossing maneuvers. Pedestrians will often be resistant to retracing their path to cross at an intersection. (*7*)

Inspection-Wiring

In the process of pulling wire across a roadway or a pedestrian pathway, make sure that traffic will not be able to run over the wire or that pedestrian traffic cannot walk on the wire. Damage can result to the conductors if the wire is traveled over. (*12*)

Inspection- Pull Boxes

During construction, adequate warnings and safeguards in the form of signs, lights, and barricades are to be used. Jacking pits or foundation holes located where pedestrians may walk must be covered with adequately braced plywood or equivalent." (12)

Maintenance

"Non-motorized projects within the State highway right of way that are partially funded by local agencies may be maintained by local agencies under a Cooperative Agreement with Caltrans." (*9*)

"If the non-motorized facility is a bike path or a walkway that connects to a local non-motorized facility, and if it is outside the limits needed for operating and maintaining the roadway, then Caltrans should seek agreement for the local agency to maintain the facility. Maintenance by the local agency can provide continuity in the maintenance of the local non-motorized system and helps demonstrate a local willingness to cooperate in the project. Maintenance provisions should be established that do not compromise the safety or operation of the highway." (*9*)

ADMINISTRATIVE AND LEGAL

The safety and needs of pedestrian traffic, as well as facilities accommodating pedestrians, are addressed at both administrative and legal levels. The following section discusses California's administrative and legal requirements regarding pedestrian issues.

Project Development

In the initial planning stages of a project, Caltrans must consider and evaluate the needs of both bicyclists and pedestrians.

Design Guidelines

The policy and criteria for the development of pedestrian facilities is located under Topic 105 in the Caltrans *Highway Design Manual*. Pedestrian facilities must include features that provide the disabled with access to the pedestrian facility. The appropriate signs, markings, and traffic control devices must be used when constructing pedestrian facilities. The specifications for the correct signing, marking, and traffic control devices are contained in the Caltrans *Traffic Manual*.

Approvals

In the case of a freeway project in which non-motorized traffic facilities do not exist in the plan, the draft and final reports should include a discussion of the projects conformity to the California Recreational Trails System Plan or the local agency's plans for non-motorized transportation facilities.

CEQA

The CEQA (California Environmental Quality Act) provides the legal mechanism for comprehensive study of possible environmental impacts of transportation improvements. While it does not single out pedestrian travel specifically, there is some evidence of special consideration given to non-highway modes of travel. For example, some rail projects are not subject to CEQA. (*11*) From the rail project exemption one may conclude that pedestrian travel in lieu of motor vehicle travel could be favored somewhat in circumstances when fuel consumption and/or air quality is critical. This is because pedestrian travel consumes no fossil fuel and creates no air pollution.

Relinquishments

The relinquishment of pedestrian facilities is treated as a part of the general roadway. The majority of relinquishment actions include corresponding facilities that were either built with the main project or acquired as part of the project. These corresponding facilities are frontage roads, streets that have been relocated, new streets to maintain service, cul-de-sac adjustments, bicycle trails and pedestrian facilities.

When relinquishments are in order, rehabilitation is governed by the following: "Rehabilitation work proposed as a condition of relinquishment must be justified. This includes corrective work (if any) on bridges, culverts, curbs, drains, pavement, pedestrian facilities, or other facilities that are part of the highway in order to place the

facility into a maintainable condition. In no case is the pavement rehabilitation design life to be in excess of 10 years." (*9*)

Application Process

In the S&H Code, Section 888 states that "Caltrans will not construct a State highway as a freeway that will result in the severance or destruction of an existing major route for non-motorized traffic and light motorcycles unless it provides a reasonable, safe, and convenient alternate route or unless such a route already exists." (*9*)

Non-motorized facilities may exist on major routes such as (*9*):

- Conventional highways or expressways.
- Sidewalks on conventional highways.
- Freeway shoulders in which bicycle traffic is permitted.
- Path within the freeway right of way.
- Path outside of the freeway right of way.
- Path outside of the roadway.

In the consideration of alternate routes, these routes must be safe and convenient for the user. The alternate route should not be out of the way for users of the route. The route should also not possess additional grades nor high-volume routes with narrow shoulders.

"Pursuant to Section 888 of the S&H Code, non motorized facilities proposed after a freeway has been constructed do not qualify as an 'alternate route' for a severed or destroyed non-motorized route. Instead such facilities are to be developed as a cooperative project under the provisions of Sections 887.6 and 888.2 of the S&H Code." (*9*)

Legal Relations and Responsibilities

"The Contractor bears a contractual obligation of providing for the convenience of the public and public traffic. The scope and limits of this obligation are in Section 7-1.08, Public Convenience, of the Standard Specifications." (12) The "public" is considered anyone passing through or affected by areas, which are under construction. This includes pedestrians and residents, as well as vehicular traffic. (12)

Traffic- Responsibilities of Resident Engineer

"If the Contractor's operations interfere with or cause hazards to vehicular or pedestrian traffic, the Resident Engineer is to contact the Contractor immediately and request correction of the deficiency. If necessary the Contractor is to be directed in writing to act at once to remedy the unsatisfactory situation. State work forces should be called upon only when necessary due to physical inability of the Contractor or their refusal to act and it is urgent for public safety to act immediately. A Contractor's failure to perform is cause for ordering cessation of operations creating the deficiency." (12)

Local Regulation of Pedestrians

The Vehicle Code in Section 21961 does not prevent local authorities from adopting their own regulations of prohibiting pedestrians from crossing roadways in areas without marked crosswalks.

Pedestrian Responsibilities

"It shall be unlawful for any pedestrian to fail to obey any sign or signal erected or maintained to indicate or carry out the provisions of this code (*CVC*) or any local traffic ordinance or resolution adopted pursuant to a local traffic ordinance, or to fail to obey any device erected or maintained..." (*5-21461.5*)

Definition of Traffic and Pedestrians

Traffic includes pedestrians, ridden animals, vehicles, streetcars, and other conveyances--either singly or together--while using any highway for purposes of travel. (*5-620*)

NEW (YEAR 2000) CALIFORNIA LEGISLATION

This section of this paper deals specifically with the four new bills approved during the 2000 legislative session and signed into law that deal with the aspect of pedestrian safety.

Assembly Bill 1475

This law amended, repealed, and added sections to the Streets and Highway Code, relating to highways to provide for the following:

This law requires "the Department of Transportation, in consultation with the Department of the California Highway Patrol, to establish and administer a Safe Routes to School construction program pursuant to authority granted under specified federal law and to use federal transportation funds for construction of bicycle and pedestrian safety and traffic calming projects." (14)

The Institute of Transportation Engineers provides guidelines for developing a "Safe Routes to School Program." (13)

Assembly Bill 1573

This law amended and renumbered Section 38048 of the Education Code, and amends Sections 22112 and 2454 of the Vehicle Code, relating to vehicles.

The previous law stated that pupils who receive home to school transportation are required to receive instruction on school bus safety once a year. The year 2000 law changes the previously existing law by the addition of a specified training subject to the already required school bus safety instruction. This additional instruction includes but is not limited to proper loading and unloading procedures and how to safely cross a street, highway or private road.

The new law exempted drivers of school buses from the flashing red signal lights and stop arm requirements at locations where the school district, in consultation with the California Highway Patrol, has determined that the use of the flashing signal lights and stop arm presents a traffic or safety hazard. However, this does not apply

where students are loading or unloading from a school bus and must cross a private road. Additionally it does not apply on highways. In the uncontrolled situations the bus drivers should safely escort the students across the roadway. The year 2000 law also requires all students to walk in front of the bus as they cross the roadway.

The year 2000 law requires the Department of the California Highway Patrol "to undertake a specific study regarding flashing red lights and stop signal arms on school buses and to report the results of that study to the Legislature on or before January 1, 2005." (15)

"The California Constitution requires the state to reimburse local agencies and school districts for certain costs mandated by the state. Statutory provisions establish procedures for making that reimbursement," however, this law provides that no reimbursement is required. (15)

Assembly Bill 2522

This law established, "the Pedestrian Safety Account in the State Transportation Fund to be available, upon appropriation, for allocation by the Department of Transportation to local governmental agencies approved for grants to undertake pedestrian safety improvement projects, including projects designed to improve facilities for pedestrians and bicyclists in areas where need has been demonstrated by high pedestrian injuries or fatalities."(17)

This law also prohibited any person from stopping and obstructing a marked or unmarked crosswalk or sidewalk with a vehicle.

Another aspect of this law is that it required the Department of Motor Vehicles to put at least one question in each test of an applicant's knowledge and understanding of the Vehicle Code. This action is to confirm that the person has read and understands pedestrian rights.

A mandatory fine of $100 is imposed by this law for a first time conviction of violating the provision that states that it is prohibited for a driver to pass another vehicle that is stopped at a marked or unmarked crosswalk for a pedestrian crossing the roadway. This law also required that the Director of Motor Vehicles include pedestrian related information in the curriculum of automobile driver education programs, driving schools, and traffic violator schools. The rights and duties of motorists as they relate to pedestrian traffic and the rights and duties of pedestrians as they relate to vehicular traffic and safety must be addressed.

Assembly Bill 2767

This legislation changed the scope of a traffic and engineering speed survey to include consideration for pedestrian safety.

Senate Bill 2185

This law added a new section (25283) to the California State vehicle code. It was directed at food-vending vehicles (i.e. "ice cream" vehicles) operating in residential areas that will stop and park. Motorists need to be warned that children may be in the area.

"Commercial vehicles engaged in vending food items on the street in a residence district shall be equipped with flashing amber warning lights displayed on

the front, sides or rear of the vehicle. The flashing amber warning lights shall be operated whenever the commercial vehicle stops and parks the vehicle..." (16)

SUMMARY

Several groups, specifically the disabled, the elderly, and children, require special consideration for pedestrian accommodations. These groups are at higher risk of involvement in pedestrian collisions because of physical or mental limitations. The Caltrans *Highway Design Manual,* the *Traffic Manual,* and the *Maintenance Manual* discuss topics, which include the design, traffic control, and maintenance of school area zones, disabled accessible grade separation structures, pedestrian traffic signals, and sidewalks.

The project development process has been established to help address pedestrian concerns by applying Caltrans' policies from the initial stages of project planning through the construction. Guidelines for the application process, design, maintenance provisions, and construction of non-motorized transportation facilities are included as part of the *Project Development Procedures Manual.*

There are several means of protecting pedestrians who must cross or walk adjacent to a state highway. School walkways, sidewalks, and curbs are facilities designated for the safe movement of pedestrians near vehicular traffic. At-grade intersections, grade separated crossing structures, at-grade crossings, and refuge islands aid in the passage of the intersecting pedestrian and vehicular routes. The maintenance, planning, design parameters, and financial responsibility guidelines of these facilities were discussed in the *Highway Design Manual,* the *Traffic Manual,* and the *Maintenance Manual.*

The *CVC* provides governing legal regulations that define the proper behavior of pedestrians, bicyclists, and motorists and the interactions among these groups. These regulations deal with sidewalks, crosswalks, intersections, and the use of bridges and tunnels.

3.0 PEDESTRIAN BEST PRACTICES

INTRODUCTION

While California has a national reputation as a leader in transportation, it can be beneficial from time to time to discover what practices and devices are in use by other agencies in the United States. Consequently, this chapter is a result of an extensive national literature search of practices dedicated to improving pedestrian safety.

Specifically, for this search, all 50 state Department of Transportation (DOT) agencies were contacted. Copies of literature documenting all practices and policies relating to pedestrian accommodation were requested from these State DOT's. The transportation agencies of the 50 largest cities in the United States were contacted and in addition, 12 Metropolitan Planning Organizations (MPO's) were also contacted. A similar request was made for literature regarding the accommodation of pedestrians from these two agency types. Federal documents and websites were consulted for pedestrian information and transportation journals were reviewed as well. During the literature search a few international sources were also obtained.

PLANNING

Design Guidance

The Transportation Equity Act for the 21st Century (TEA-21) became Public Law 105-178 on June 9, 1998. This law "authorizes the Federal surface transportation programs for highways, highway safety, and transit for the 6-year period 1998-2003." (*96*) The pedestrian applicable section of TEA-21 states, "Bicycle transportation facilities and pedestrian walkways shall be considered, where appropriate, in conjunction with all new construction and reconstruction of transportation projects except where bicycle and pedestrian use are not permitted." It is also stated that, "Transportation plans and projects shall provide due consideration for safety and contiguous routes for bicyclists and pedestrians." (*95*)

In response to this act, the USDOT, with contributions from public agencies, professional associations, and advocacy groups, issued a policy statement regarding the goal of integration of walking and bicycling into the transportation infrastructure. There are four parts to the policy statement issued. (*97*)

1. Pedestrian and bicycle routes, "shall be established in new construction and reconstruction projects in all urbanized areas," unless at least one of three conditions are met.
   - Pedestrians and bicyclists are prohibited by law.
   - Costs would be excessively disproportionate to the projected use.
   - An absence of need has been established.
2. Paved shoulders should be included on rural roadways used by more than 1000 vehicles per day to provide accommodation for pedestrians and bicyclists.

3. Pedestrian facilities "shall be designed, constructed, operated, and maintained" to accommodate all levels of pedestrian abilities. Disabled pedestrian should be able to travel safely and independently.
4. Conditions for pedestrians and bicyclists shall be improved by the development of the infrastructure through the following steps:
   - "Planning projects for long-term."
   - "Addressing the needs of pedestrians and bicyclists to cross corridors."
   - "Approving exceptions at the senior level."
   - "Designing facilities to the best currently available standards and guidelines."

Issues of Pedestrian Demand

Pedestrian Travel Data

The 1990 Nationwide Personal Transportation Study (NPTS) found that walking trips account for 7.2% of the total trips made. Approximately 15% of the total pedestrian trips were work related. Other purposes for walking were family and personal reasons—accounting for 28% of total walking trips; civic, educational, and religious purposes—accounting for 18% of total walking trips; social and recreational trips—accounting for 37% of walking trips; and 2% of total walking trips were categorized as other. The 1990 NPTS also revealed that more than a quarter of trips are one mile or less in length and that 53% of people live two miles or less from a transit stop. (*25*)

Significance of Projecting Non-Motorized Demand

Transportation planners and policy makers are faced with the decisions concerning the most advantageous application of transportation funds. They must ensure that proposed facilities and rehabilitation of facilities would provide the surrounding community with the greatest benefit. The level of non-motorized demand will be impacted by proposed transportation projects, policies, and future changes in land use and socioeconomic factors.

The 1999 *Guidebook on Methods to Estimate Non-Motorized Travel: Overview of Methods* was written to help answer several questions regarding the demand on non-motorized facilities (*26*):

- How many pedestrians and bicyclists will be attracted by a new non-motorized facility?
- How many new pedestrians and bicyclists will be attracted by an improved non-motorized facility?
- What types of improvements, or combinations of improvements, will attract the greatest number of non-motorized users?
- How will the non-motorized facility (new or improved) affect motorized traffic?

This guidebook also lists the following reasons that estimating non-motorized is essential to transportation planners (*26*):

- Estimating the benefits of a proposed project, such as number of users served, reductions in automobile emissions and energy consumption, or time and cost savings to travelers;
- Prioritizing projects based on the greatest benefit to existing users or on the greatest payoff in attracting new bicyclists or walkers;
- Planning bicycle or pedestrian networks and identifying and correcting deficiencies in existing networks, based on desired travel patterns and facility characteristics; and
- Planning for bicycle and pedestrian safety by developing exposure information for crash/safety models. In the United States in particular, two recent developments underscore the importance of quantifying demand:

- The 1994 U.S. Supreme Court Dolan vs. Tigard decision. This decision mandates that local jurisdictions quantify proposed bicycle project benefits when the project involves private land dedications under master plans.
- The 1998 passage of the TEA-21. TEA-21 continues and expands provisions of its predecessor, the Intermodal Surface Transportation Efficiency Act of 1991 (ISTEA), to improve facilities and safety for bicycles and pedestrians. TEA-21 places an emphasis on quantifying the air quality and congestion alleviation benefits of projects, including bicycle and pedestrian projects to receive funding under the Congestion Mitigation and Air Quality (CMAQ) program (22). TEA-21 also adds "bicycle transportation and pedestrian walkways" to the list of eligible projects for National Highway System Funds and expands eligibility for funding under other programs (23). Estimates of the benefits of bicycle and pedestrian projects will be useful in competing for funding under these programs.

Adjustments in Pedestrian Travel Behavior

Pedestrian facilities will accommodate a wide range of users with different characteristics and needs. Introduction of a safe, comfortable, and convenient pedestrian route will change the existing travel behavior in the surrounding region.

High quality walking facilities are likely to increase the amount of pedestrian travel for recreation and errand activities. When a desirable pedestrian route is introduced, destination choices may be altered. A closer location may be chosen over a previously distant site accessed by a car trip.

Trip scheduling may differ in a pedestrian friendly environment. People may choose to walk to close locations when parking places are difficult to find or will choose times to walk when traffic is lighter for the reason of perceived safety.

Pedestrian facility will serve pedestrians with different needs and abilities. Each facility will affect different portions of the population in varying ways. (*26*)

Methods of Estimating Non-Motorized Travel

The 1999 *Guidebook on Methods to Estimate Non-Motorized Travel: Overview of Methods* discusses eleven methods used to determine demand estimation, relative demand potential, supply quality analysis, and supporting tools and techniques. The previous terms are described and the methods briefly explained in Table 3-1 on pages 7 through 11. Advantages and disadvantages, in addition to a rating and applicability are also listed in Table 3-1.

The guidebook also includes an overview of each method, if the method estimates demand at the facility level or area-wide, two real examples of the application, and a rating of the method in five distinct categories. The evaluation in each category is in the form of a continuum between two extreme ratings.

1. Ease of Use – Rated easy to difficult. Easy signifies a layperson with basic abilities could apply method; while difficult signifies "extensive specialized training" is necessary for correct application.
2. Data Requirements - Rated minimal to extensive. Minimal signifies primarily existing data is necessary and extensive signifies major new data collection efforts are required.
3. Accuracy - Rated low to high. Low signifies forecasts have not predicted observations and high signifies that predictions closely related to actual demand.
4. Sensitivity to Design Factors - Rated low to high. Low signifies method cannot relate specific design characteristics to demand and high signifies the impact of multiple design factors and their interaction can be assessed.
5. Widely Used - Rated no to yes. No signifies few applications have been identified and yes signifies that the method is extensively used in practice.

Table 3-1: Overview of Available Methods to Estimate Pedestrian Travel

Purpose	Method	Description	Rating
Demand Estimation		Methods that can be used to derive quantitative estimates of demand.	
	Comparison Studies	Methods that predict non-motorized travel on a facility by comparing it to usage and to surrounding population and land us characteristics of other similar facilities. Application: Area/Regional	**Ease of Use:** easy — difficult **Data Requirements:** minimal — extensive **Accuracy:** low — high **Sensitivity to Design Factors:** low — high **Widely Used:** no — yes
		Advantages: Easy to understand and apply. Disadvantages: Only allows rough estimate. It is often difficult to find a truly applicable comparative facility.	
	Aggregate Behavior Studies	Methods that relate non-motorized travel in an area to its local population, land use, and other characteristics, usually through regression analysis. Application: Area/Regional	**Ease of Use:** easy — difficult **Data Requirements:** minimal — extensive **Accuracy:** low — high **Sensitivity to Design Factors:** low — high **Widely Used:** no — yes
		Advantages: Aggregate behavior studies have developed models isolating factors that relate to non-motorized travel. Quantifiable relationships between factors and modal split have been found. The results may be valuable for the trip generation component of regional travel models. Disadvantages: The method is unable to explain relationships and is unsuccessful in predicting modal split when applied to alternate areas. Average characteristics are used for the model and variation of population is not considered. Factors that are not easily obtained are ignored. Data is primarily obtained form census and describes only work trips. Environmental conditions are not considered.	

Table 3-1: continued

Purpose	Method	Description	Rating
	Sketch Plan Methods	Methods that predict non-motorized travel on a facility or in an area based on simple calculations and rules of thumb about trip lengths, mode shares, and other aspects of travel behavior. Application: Facility	**Ease of Use:** easy — difficult **Data Requirements:** minimal — extensive **Accuracy:** low — high **Sensitivity to Design Factors:** low — high **Widely Used:** no — yes
		Advantages: Method is easy to understand and apply. Careful application can result in a reasonable estimate of users. It is best suited for use in planning to compare location and alternatives for facilities. Disadvantages: Method is based on assumptions concerning local behavior and may not be an accurate account for facility characteristics, surrounding population, destination, other competing modes of travel, or network. Also the developed model may not be applicable to other geographic areas.	
	Discrete Choice Models	Models that predict an individual's travel decisions based on characteristics of the alternatives available to them. Application: Facility & Area/Regional	**Ease of Use:** easy — difficult **Data Requirements:** minimal — extensive **Accuracy:** low — high **Sensitivity to Design Factors:** low — high **Widely Used:** no — yes
		Advantages: This method is the best available tool for forecasting travel behavior impacts. It is based on local survey data which will enable the isolation and quantification of personal and environmental factors. Disadvantages: Method requires extensive knowledge in discrete modeling techniques. It is impossible to consider all factors that may that contribute to the results and a model developed for a particular location may not be applicable to others.	

Table 3-1: continued

Purpose	Method	Description	Rating
	Regional Travel Models	Models that predict total trips by trip purpose, mode, and origin/destination and distribute their trips across network of transportation facilities based on land use characteristics such as population and employment and on characteristics of the transportation network. Application: Facility & Area/Regional	**Ease of Use:** easy — difficult **Data Requirements:** minimal — extensive **Accuracy:** low — high **Sensitivity to Design Factors:** low — high **Widely Used:** no — yes
		Advantages: Regional travel models have been established for all major urban areas in the US. Models can help analyze the modal choice of travelers. With added data collection to aid in model improvements, regional travel models can be an effective tool. Disadvantages: The development of models was based on established automobile type distances. Environmental considerations will be important to the non-motorized portion of the model which will necessitate additional data collection. Trips made for purely recreational purposes have not been included in regional travel models. Development and application of models requires expertise and the use of special software.	
Relative Demand Potential		Methods that do not predict actual demand levels, but which can be used to assess potential demand for or relative levels of non-motorized travel.	
	Market Analysis	Methods that identify a likely or maximum number of bicycle or pedestrian trips that may be expected given an ideal network of facilities. Application: Area/Regional	**Ease of Use:** easy — difficult **Data Requirements:** minimal — extensive **Accuracy:** low — not rated — high **Sensitivity to Design Factors:** low — high **Widely Used:** no — yes
		Advantages: This method will result in a maximum estimate of non-motorized trips for a facility. With this method the potential use of different facilities can be compared. Disadvantages: A rough estimate for the maximum potential use is attained. It is not useful in determining trends due to the improvement of a facility and is not valuable in addressing the factors affecting the choice to bike or walk.	

Table 3-1: continued

Purpose	Method	Description	Rating
	Facility Demand Potential	Methods that use local population and land use characteristics to prioritize projects based on their relative potential for use. Application: Facility	**Ease of Use:** easy — difficult **Data Requirements:** minimal — extensive **Accuracy:** low — not rated — high **Sensitivity to Design Factors:** low — high **Widely Used:** no — yes
		Advantages: Can be useful in determining priority for the location of facility improvements especially when deficiencies and potential demand are being considered. Most data required can be obtained from the census or local land use databases. Disadvantages: This method is not helpful in determining which type of improvement for a given location would result in the greatest increase in use or the degree of an increase. Relative use between areas is measured not the quantitative use of a specific facilities.	
Supply Quality Analysis		Methods that describe the quality of non-motorized facilities (supply) rather than the demand for such facilities. These may be useful for estimating demand if demand can be related to the quality of available facilities.	
	Bicycle and Pedestrian Compatibility Measures	Measures that relate characteristics of a specific facility such as safety to its overall attractiveness for bicycling or walking. Use: Facility	**Ease of Use:** easy — difficult **Data Requirements:** minimal — extensive **Accuracy:** low — not rated — high **Sensitivity to Design Factors:** low — high **Widely Used:** no — yes
		Advantages: Can be useful in prioritizing the facilities in need of improvements and which improvements will be the most advantageous. Disadvantages: The affect of discontinuities such as intersections and the overall route made up of several segments cannot be measured. All factors may not be considered or extensive data collection may be necessary. The number of trips per segment is not predicted.	

Table 3-1: continued

Purpose	Method	Description	Rating
	Environment Factors	Measures of facility and environment characteristics at the area level that describe how attractive the area is to bicycling or walking. Application: Area/Regional	**Ease of Use:** easy — difficult **Data Requirements:** minimal — extensive **Accuracy:** low — not rated — high **Sensitivity to Design Factors:** low — high **Widely Used:** no — yes
Supporting Tools and Techniques		Analytical methods to support demand forecasting.	
	Geographic Information Systems	Emerging information management tools, with graphic or pictorial display capabilities that can be used in many ways to evaluate both potential demand and supply quality. Application: Facility & Area/Regional	**Ease of Use:** easy — difficult **Data Requirements:** minimal — extensive **Accuracy:** low — not rated — high **Sensitivity to Design Factors:** low — not rated — high **Widely Used:** no — yes
	Preference Surveys	Survey techniques that can be use on their own to determine factors that influence demand, and that also serve as the foundation for quantitative forecasting methods such as discrete choice modeling. Application: Facility & Area/Regional	**Ease of Use:** easy — difficult **Data Requirements:** minimal — extensive **Accuracy:** low — not rated — high **Sensitivity to Design Factors:** low — not rated — high **Widely Used:** no — yes

SOUCE: 1999 *Guidebook on Methods to Estimate Non-Motorized Travel: Overview of Methods*

Table 3-1 would be useful to transportation professionals in selecting appropriate pedestrian travel estimation methods based upon the needs and available resources.

Capacity and Level of Service

The *Capacity Analysis of Pedestrian and Bicycle Facilities: Recommended Procedures for the "Pedestrians" Chapter of the Highway Capacity Manual* states that some of the procedures in the *Highway Capacity Manual* (HCM) rely upon incomplete and outdated information. This study offers recommendations for improvements.

The study recommended the simplified body dimensions for a stationary pedestrian should be an ellipse of 50cm by 60cm (20in by 24in). The total area of the elliptical model for the standing pedestrian is $0.3m^2$ ($3.2ft^2$). For a walking pedestrian an additional $0.75m^2$ ($8.1ft^2$) is recommended.

The Capacity Analysis of Pedestrian and Bicycle Facilities recommends that modifications be made to the existing Level of Service (LOS) guidelines in the *HCM*. These recommended adjustments and current standard as shown in Table 3-2. This can help when analyzing sidewalk capacities.

Table 3-2: Existing and Recommended Walkway LOS.

		Existing HCM walkway LOS criteria			
		Recommended HCM walkway LOS criteria			
Level of Service (LOS)	Characteristic	Space (m^2/ped)	Flow Rate (ped/min/m)	Average Speed (m/s)	v/c ratio
A	At walkway LOS A, pedestrians move in desired paths without altering their movements in reaction to other pedestrians. Walking speeds are freely selected, and conflicts between pedestrians are unlikely.	≥ 12	≤ 7	≥ 1.32	0.08
		≥ 5.6	≤ 16	≥ 1.30	0.21
B	At walkway LOS B, sufficient area is provided to allow pedestrians to freely select walking speeds, to bypass other pedestrians, and to avoid crossing conflicts with others. At this level, pedestrians begin to be aware of other pedestrians and to respond to their presence in the selection of walking space.	3.7-12	7-23	1.27-1.32	0.08-0.28
		3.7-5.6	16-23	1.27-1.30	0.21-0.31
C	At LOS C, sufficient space is available to select normal walking speeds and to bypass other pedestrians in primarily unidirectional streams, Where reverse-direction or crossing movements exist, minor conflicts will occur, and speeds and volume will be somewhat lower.	2.2-3.7	23-33	1.22-1.27	0.28-0.4
		2.2-3.7	23-33	1.22-1.27	0.31-0.44
D	At LOS D, freedom to select individual walking speed and to bypass other pedestrians is restricted. Where crossing or reverse-flow movements exist, the probability of conflict is high, and its avoidance requires frequent changes in speed and position. LOS D provides reasonably fluid flow; however, considerable friction and interaction among pedestrians is likely to occur.	1.4-2.2	33-49	1.14-1.22	0.4-0.6
		1.4-2.2	33-49	1.14-1.22	0.44-0.65
E	At LOS E, virtually all pedestrians would have their normal walking speed restricted, requiring frequent adjustment of gait. At the lower range of this LOS, forward movement is possible only by "shuffling." Insufficient space is provided for passing of slower pedestrians. Cross or reverse-flow movements are possible only with extreme difficulties. Design volumes approach the limit of walkway capacity, with resulting stoppages and interruptions to flow.	0.6-1.4	49-82	0.76-1.14	0.6-1.0
		0.75-1.4	49-75	0.75-1.14	0.65-1.0
F	At LOS F, all walking speeds are severely restricted, and forward progress is made only by "shuffling." There is frequent, unavoidable contact with other pedestrians, Cross and reverse-flow movements are virtually impossible, Flow is sporadic and unstable. Space is more characteristic of queued pedestrians than of moving-pedestrian streams.	≤ 0.6	var.	≤ 0.76	var.
		≤ 0.75	var.	≤ 0.75	var.

SOURCE: *Capacity Analysis of Pedestrian and Bicycle Facilities: Recommended Procedures for the "Pedestrians" Chapter of the Highway Capacity Manual*

Pedestrian Delay at Intersections

Methods for projecting pedestrian delay at signalized intersections and methods for projecting pedestrian delay at unsignalized intersections are identified and discussed in the report, *Capacity Analysis of Pedestrian and Bicycle Facilities: Recommended Procedures for the "Pedestrians" Chapter of the Highway Capacity Manual.* (*27*) The *Highway Capacity Manual* currently does not contain a delay measure for pedestrians at intersections. Table 3-3 lists the recommended LOS standards according to pedestrian delays at signalized intersections.

Table 3-3: Recommended Pedestrian LOS Criteria for Signalized Crossing Delays

Level of Service LOS	Average Delay Per Pedestrian (seconds)	Likelihood of Pedestrian Noncompliance
A	< 10	Low
B	10-20	
C	20-30	Moderate
D	30-40	
E	40-60	High
F	60	Very High

SOURCE: *Capacity Analysis of Pedestrian and Bicycle Facilities: Recommended Procedures for the "Signalized Intersections" Chapter of the Highway Capacity Manual (27)*

Funding for Pedestrian Projects

Pedestrian projects may qualify to receive funds from the Federal-Aid highway, transit, safety, and other programs. Table 3-4 summarizes some of the sources by the program, type of funds, and applicable qualifications to receive the funds. (*94*)

Table 3-4: Federal-Aid Funding Sources for Pedestrian Projects

PROGRAM	FUNDS	QUALIFICATION
Federal-Aid Highway Program	National Highway System Funds	Pedestrian facilities may be constructed adjacent to any highway on the National Highway System including Interstates.
Federal-Aid Highway Program	Surface Transportation Program (STP)	Pedestrian related non-construction projects such as maps, brochures, and public service announcements, in addition to pedestrian facilities are eligible.
Federal-Aid Highway Program	Federal Lands Highway Program	Pedestrian provisions are eligible in conjunction with roads, highways, or parkways.

Table 3-4: continued

PROGRAM	FUNDS	QUALIFICATION
Federal-Aid Highway Program	National Scenic Byways Program	Construction of pedestrian facilities along a scenic byway is eligible.
Federal-Aid Highway Program	High Priority Projects and Designated Transportation Enhancement Activities	Projects identified by TEA-21 which include pedestrian, trail, traffic calming, and others for communities throughout the country.
Federal Transit Program	Urbanized Area Formula Grants, Capital Investment Grants and Loans, and Formula Program for Other than Urbanized Area	Funds may be used for pedestrian projects improving access between transit facilities and other modes of transportation. Eligible projects can be "pedestrian and bicycle access to a mass transportation facility." (Title 49 U.S.C amended by TEA-21)
Federal Transit Program	Transit Enhancement Activity	One percent of Urbanized Area Formula Grants set aside that may be used for pedestrian walkways, facilities, and other items.
Highway Safety Programs	State and Community Highway Safety Grants	States can be eligible for funding by submitting a Performance Plan and Highway Safety Plan. (Section 402)
Highway Safety Programs	Highway Safety Research and Development	Projects eligible for funding include research, development, demonstrations, and training relating to the improvement of highway safety. (Section 403)

SOURCE: *Bicycle And Pedestrian Provisions Of The Federal-Aid Program As Amended By The Transportation Equity Act For The 21st Century A Summary.*

Generally the matching consists of 80% federal funds with a matching by state or local agencies of 20%. However, some pedestrian projects are eligible for exceptions as follows (*94*):

- Both Section 402 Highway Safety Funds and Federal Lands Highway projects are completely federally funded.
- Projects eliminating hazards are up to 90% federally funded.
- Individual Transportation Enhancement Activity projects under the STP may have a larger or smaller share of federally funding but the overall federal share for the state's Transportation Enhancement Program must be 80%.
- States containing a higher percentage of federal land are eligible for greater shares of federal money in proportion to federal land area.
- The state and/or local matching funds for Federal-Aid Highway projects may include in-kind contributions.

WALKWAYS

Walkways are facilities to provide pedestrians safe mobility with some separation from motorized traffic. The three types of walkways are sidewalks, shoulders, and paths. Sidewalks are paved surfaces located adjacent to the roadway having separation provided by a curb and/or planting strip. The use of shoulders to accommodate pedestrians is not ideal but wide shoulder sections may be adequate for light pedestrian travel along some rural or suburban regions. Paths, paved or unpaved, are separated pedestrian facilities, which often have their own alignment and are sometimes shared with bicycles.

Need for Sidewalks

Sidewalks increase safety by physically separating pedestrians from vehicular traffic by a curb and/or setback distance. Pedestrian considerations should be made when future activity can be expected—even before there may be an actual need. This may reduce the overall related costs.

The ITE Technical Council Committee 5A-5 has reported that sidewalks "reduce the incidence of pedestrian collisions, injuries, and deaths in residential areas and along two-lane roadways." That same committee recommends sidewalks be provided in all urban areas, along all public highways other than interstates, all commercial areas the public is expected, and between all commercial transportation stops and public areas. (*30*)

There are four main relevant traffic factors useful in the determination of the need for a sidewalk in a specific area. These factors are:

- Pedestrian Volumes
- Motorized Vehicular Volumes
- Relative Timing of the Volumes
- Vehicular Speeds

Table 3-5 appears in the *Pedestrian Facilities Guidebook* from the Washington State Department of Transportation (WSDOT) summarizing the 1994 AASHTO green book guidelines for situations that require a walkway or sidewalk. (*31*)

Table 3-5: Guidelines for Providing Walkways and Sidewalks

- *Develop sidewalks as integral parts of all city streets.*
- *If pedestrian activity is anticipated, construct sidewalks as part of street development.*
- *Give consideration to connecting the nearby urban communities with sidewalks, even though pedestrian traffic may be light.*
- *Sidewalks in rural and suburban areas are needed at schools, local businesses, and industrial plants that result in pedestrian concentrations.*
- *Traffic volume-pedestrian warrants for sidewalks along highways have not been established. In general, whenever the roadside and land development conditions are such that pedestrians regularly move along a main or high-speed highway, they should be furnished with a sidewalk or path area, as suitable to the conditions.*

Table 3-5: continued

- *The higher speeds of traffic and general absence of lighting in rural areas reinforce the need for sidewalks. Available data suggests that sidewalks in rural areas reduce pedestrian/motor vehicle collisions.*
- *As a general practice, sidewalks should be constructed along any street or highway not provided with shoulders, even though pedestrian traffic may be lighted. Sidewalks built along rural highways should be well-removed form the traveled way, separated by a ditch or as much space as available.*

SOURCE: 1997 *Pedestrian Facilities Guidebook (WSDOT)*

Sidewalk Design Parameters

The following table (3-6) was incorporated into both the 1998 *The Design and Safety of Pedestrian Facilities from ITE* and 1996 *Everyone is a Pedestrian* from the New York Department of Transportation (NYDOT). It lists the guidelines for installation of sidewalks for various conditions in suburban and urban areas. The left column lists the surrounding land use, functional classification of roadway, and/or dwelling unit density. The central column provides corresponding recommendations for the inclusion of sidewalks on new urban or suburban streets. The right column provides recommendations for sidewalk installation if not currently provided for existing urban and suburban streets. (*32,33*)

Table 3-6: Guidelines for Installing Sidewalks

Land-Use/Roadway Functional Classification/and Dwelling Unit	New Urban and Suburban Streets	Existing Urban and Suburban Streets
Commercial and Industrial (All Streets)	Both Sides.	Both sides. Every effort should be made to add sidewalks where they do not exist and complete missing links.
Residential (Major Arterials)	Both Sides.	Both sides.
Residential (Collectors)	Both Sides.	Multifamily--both sides.
		Single family dwellings--prefer both sides; require at least one side.
Residential (Local Streets) More than 4 Units Per Acre	Both Sides.	Prefer both sides; require at least one side.
Residential (Local Streets) 1 to 4 Units Per Acre	Prefer both sides; require at least one.	A least 4-feet shoulder on both sides required.
Residential (Local Streets) Less than 1 Units Per Acre	One side preferred; shoulder on both sides required.	One side preferred, at least 4-feet shoulder on both sides required.

NOTES:

1) Any local street within two blocks of a school site hat would be on a walking route to school--sidewalk and curb and gutter.
2) Sidewalks may be omitted on one side of a new street where that side clearly cannot be developed and where there are no existing or anticipated uses that would generate pedestrian trips on that side.
3) Where there are service roads, the sidewalk adjacent to the main road may be eliminated and replaced by a sidewalk adjacent to the service road on the side away from the mail road.
4) For rural roads not likely to serve development, a shoulder at least 4 feet in width, preferably 8 feet on primary highways, should be provided. Surface material should provide a stable, mud-free walking surface.

SOURCE: Knoblauch et.al. *Investigation of Exposure Based Pedestrian Areas: Crosswalks. Sidewalks. Local Streets and Maior Arterials.* FHWA/RD-88/038. 1988

Obstacles

The effective or clear width of a sidewalk is defined as the total width of the sidewalk surface minus potential obstacles and the shy distance from buildings and obstacles (shy distance is the distance people leave between themselves and buildings and obstacles). The effective width is also referred to as through pedestrian zone. Some typical obstacles are newspaper stands, trash bins, planters, benches, mailboxes, utility poles, signs, vegetation, and fire hydrants.

Table 3-7 lists potential sidewalk obstructions and the clearance lost when they are present. An additional 0.5m (1.5ft) (shy distance) should be also added to these lengths to increase the comfort in passing beside obstructions. (*34*)

Table 3-7: Walkway Obstructions

Obstruction*	meters**	(feet)**
Light Poles	0.8-1.1	(2.5-3.5)
Traffic Signal Poles and Boxes	0.9-1.2	(3.0-4.0)
Fire Alarm Boxes	0.8-1.1	(2.5-3.5)
Fire Hydrants	0.8-0.9	(2.5-3.0)
Traffic Signs	0.6-0.8	(2.0-2.5)
Parking Meters	0.6	(2.0)
Mailboxes	1.0-1.1	(3.2-3.7)
Telephone Booths	1.2	(4.0)
Benches	1.5	(5.0)
Waste Baskets	0.9	(3.0)
Trees	0.9-1.2	3.0-4.0
Trees with Pavement Cut	1.5-1.8	5.0-6.0
Planting Boxes	1.5	(5.0)
Newsstand	1.2-4.0	(4.0-13.0)
Awning Poles	0.8	(2.5)

*Another 0.5m (1.5ft) must be subtracted for each obstruction to determine "effective" sidewalk width.

**Amount of walkway width lost (curb to edge of obstruction or building face to edge of obstruction).

SOURCE: *Statewide Bicycle and Pedestrian Master Plan* (Lousiana DOT)

Drain grates, manhole covers, and other utility coverings should be located out of the pedestrian travel path whenever possible. If unavoidable, the ADAAG requires that covers be flush with the surface and no opening may be larger than 1.3cm (0.5in).

The Americans with Disabilities Act Accessibility Guidelines (ADAAG) also requires that "objects protruding from walls (e.g. signs, fixtures, telephones, canopies) with their leading edge between 685mm and 2030mm (27in and 80in) above the sidewalk surface shall protrude no more than 100mm (4in) into any portion of the public sidewalk." (*33*)

Sources disagree about the acceptable height of vertical obstructions. The ADAAG requires 2.1m (7.0ft) above the sidewalk surface (*35,36*). Other sources state that the minimum height should be at least 2.4m (8.0ft).

When possible, tall vertical walls should not be adjacent to walkways because of the sense of confinement they may create. Preferably the walls should be terraced back for the comfort of the pedestrian. Vertical walls should be textured attractively and climbing plants should be used for aesthetics. (*31*)

Sidewalk Widths

The ADAAG standard requires a minimum sidewalk width of 0.915m (3ft) but a recommended standard is 1.5m (5.0ft). Where the 1.5m (5.0ft) width cannot be maintained, a 1.5m by 1.5m (5ft by 5 ft) area must be provided at least every 60m (200ft) to allow passing. In general, the minimum width requirements refer to the clear width of the sidewalk, which was defined in the previous section on obstructions. Larger widths are suggested where a sidewalk is located between a curb and vertical barrier, immediately adjacent to a curb, or in commercial and industrial areas. (*30*)

The typical minimum standard sidewalk clear width is 1.5m (5ft). When the sidewalk is located immediately adjacent to the roadway without a buffer, the minimum clear width should be 1.8m (6.0ft). An additional 0.6m (2.0ft) of sidewalk should be provided when parking is allowed along the sidewalk's pedestrian travel-way to allow space for opening car doors.

A minimum 1.5m (5.0ft) clear width is sufficient to accommodate:

- Disabled passing and turning maneuvers.
- Children at play.
- Pedestrian passing without leaving sidewalk.
- Users of shopping carts, strollers, wheelchairs, and walkers.
- Waiting pedestrians at crossing areas.

The proper width of the sidewalks should be dependent on the peak pedestrian flows rather than the average. The 1998 *Design and Safety of Pedestrian Facilities* recommends a minimum sidewalk widths of 2.4m (8.0ft) in the central business district, 1.5m (5ft) with at least 0.6m (2.0ft) planting strip or 2.1m (7.0ft) without planting strip in commercial/industrial areas, 1.5m (5.0ft) with at least 0.6m (2.0ft) planting strip for residential arterials and collectors. For local streets a minimum width of 1.5m (5.0ft) with at least 0.6 m (2.0ft) planting strip for local streets with densities greater than four dwelling units per acre and 1.2m (4.0ft) with at least a 0.6m (2.0ft) planting strip for densities less than 4 dwelling units per acre. It is desirable to provide wider planting strips when possible. (*31*) Both the Oregon and Florida Department of Transportations recommend a 1.8m (6.0ft) planting strip. (*36, 37*)

"For state roadways that travel through business, shopping, and commercial areas, pedestrian data must be gathered to demonstrate appropriate sidewalk widths," according to the 1998 *Statewide Bicycle and Pedestrian Master Plan*. (*34*)

Some factors that should affect the designed width of a sidewalk in a given area are:

- Pedestrian volumes
- Land use
- Roadside environment
- Space in right-of-way
- Pedestrian characteristics
- Traffic characteristics
- Available funding
- Local preferences

In areas where the pedestrian travel will not be high, unnecessarily wide and unused sidewalks may be uninviting to prospective pedestrians.

Buffers

Buffers, also referred to as planting strips, landscaped strips, or setbacks, should be incorporated into all sidewalk sections when feasible. They should be landscaped with vegetation that needs little maintenance and watering as well as roots that will not buckle the sidewalk. "Only along the most constricted state roadways should a sidewalk be located directly adjacent to the curb." (*34*)

The absence of buffers can be dangerous and uncomfortable to the pedestrian. Vertical curbs, for added protection, should be provided when buffers are not present.

A setback of over 5ft is desirable between the curb and sidewalk and should be provided if at all possible. This increases pedestrian safety and reduces splashing from passing vehicles in wet weather. It also creates a space for some of the roadway obstacles mentioned previously in the section on obstacles. The minimum setback planted with trees should be 1.2m (4ft). If this it not possible, a minimum width of 0.6m (2ft) can be used and can be seeded, sodded or paved. For buffer widths less than 0.6m (2ft) the separation must be paved.

Listed below are some advantages and disadvantages to a specific type of buffer—the planting strip.

Advantages of Planting Strips

- Increases room for trees, signposts, poles, mailboxes, fire hydrants, etc.
- Decreases splashing on pedestrians.
- Enhances the feeling of safety by pedestrians.
- Creates space for vehicles to yield to pedestrians when entering a driveway.
- Produces more aesthetically pleasing environment.
- Allows opportunity to align crosswalks and curb cuts with sidewalk.
- Enhances accessibility for wheelchair by allowing driveway cuts within strip.

Disadvantages of Planting Strips

- Maintenance is required, and varies depending on the type of landscaping selected.
- If not designed and maintained properly, landscaping may hinder visibility and cause security problems.
- Root growth can damage adjacent paved surfaces if not protected.

Sidewalks or walkways should not be placed between drainage ditches and the roadway. Where no curbing exists, the pedestrian route should be along the far edge of the right-of-way distanced from traffic.

Sidewalks may not be located directly adjacent to travel lanes where the design speed is 70 km/h (45mph) or the posted speed is greater than 65km/h (40mph). While planting strips are preferred, shoulder barriers (i.e. asphalt curb), bicycle lanes or parking lanes are acceptable. (*35*)

Curbs

Vertical curbs increase the protection of pedestrians by creating a physical barrier between the pedestrian traffic and vehicular traffic; consequently, their use is strongly recommended. The use of vertical curbs also prevents water from entering the pedestrian path, deters cars from parking on sidewalks, and at corner locations is a factor used by visually impaired pedestrians to comprehend that an intersection has been reached.

An alternate curb is the roll-type curb, which is less expensive to install, and individual driveway cuts are unnecessary. The curb is at approximately a 45-degree angle to the roadway and provides less protection to pedestrians and roadway hardware.

The absence of a curb increases the danger to a pedestrian because vehicles are able to easily enter the pedestrian route at any point.

Sidewalk Grades and Cross-Slopes

The ADA limits the maximum grade on all accessible routes between public buildings, facilities, or services to 5% (1:20) but the minimum necessary slope should be used. A maximum slope of 8.33% (1:12) is allowable for a distance of 9.1m (30ft) or less if handrails and level landings are provided.

An 8.33% (1:12) grade may be acceptable for a distance of up to 9.1m (30ft) if a level area of 1.5m (5.0ft) is provided on each side of a slope greater than 5% (1:20) for an accessible route at a building. For any slope greater than 5% level areas must be provided for every 0.76 m (2.5ft) change in elevation. This is not a recommended practice and a longer grade with a slope less than 5% (1:20) is preferred. (*30*)

It is also recommended that the maximum grade on all public right-of-ways be limited to 5% (1:20) but the maximum grade of a sidewalk is limited to the grade of the adjacent roadway.

The ADAAG limits the cross-slope of a walkway to 2% (1:50). At locations of curb ramps and where a driveway passes through the pedestrian walkway, a steeper slope is necessary. In these cases a level landing surface of at least 0.915m (3ft) is specified by the ADAAG but Florida, New Jersey, and Portland, Oregon design standards require a level landing surface width specification of 1.2m (4ft). (*30,37,38,39*)

Side slopes adjacent to the walkway should not exceed 33% (1:3). A level area of at least 1.2m (4ft) is recommended beside the walkway. Protective railing must be provided in areas where a drop is located within 1.2m (4ft) of a walkway and that drop is greater than 0.8m (2.5ft). The railing must span the slope. The recommend height of the railing for walkways is 1.1m (3.5ft) and 1.4m (4.5ft) for multi-use trails. The

railings should not contain any holes that would allow the passage of a 10cm (4in) ball (*31*).

Material and Surfaces

All surfaces used for walkways must be "stable, firm, and slip resistant " according to the ADA guidelines. The material should resist buckling and be maintained easily.

Portland Cement Concrete (PCC) is the preferred surface due to its smoothness, durability, and expected longevity (40 years). Asphalt Concrete Pavement (ACP) may be acceptable if a surface similar to PCC is obtained. However the associated maintenance and the overall life (15-20 years) are less desirable. Bricks may also be examined as an alternate surface when they are laid smooth, the surface remains slip resistant when wet, and the long-term maintenance costs have been considered. Bricks can also be more pleasing aesthetically. Other options are the use of colored concrete stamped to resemble bricks or PCC or ACP with a brick border. (*30*)

Other commonly used surface materials are tile or stone. (*30*) "Special districts and downtown streets often incorporate special paving into the design of sidewalks and pedestrian areas, such as stamped or colored concrete, brick, or other unit-pavers." (*31*) While aesthetically pleasing, these types of pavements often require more maintenance.

These special paving techniques may also be used beside driveway crossings and curb cuts to draw attention to the changing slopes.

Sidewalk Maintenance Rating System

The Adirondack/Glens Falls Transportation Council uses a rating system, which is described in the Glens Falls Sidewalk Evaluation and Rating Manual. This system assesses the necessity of repairs or replacements of the city's sidewalks. Four factors are used in this evaluation—physical condition, street functional classification, proximity to pedestrian generators, and ADA compliance. Guidelines for the assignment of numerical points in each category are given in the rating manual to evaluate the sidewalk.

A description of each locale, its condition, and the numerical point values are entered into a spreadsheet program. Using consistent appraisals, the sidewalks in the most need of attention will be able to receive a portion of the limited funds appropriated for repair and replacement. (*40*)

Shoulders

Shoulders are an important portion of the overall roadway design. The AASHTO green book states that shoulders are desirable on all highways and urban arterials. In addition to structural benefits, shoulders accommodate the following (*41*):

- Occasional pedestrian travel.
- Bicycle travel.
- Disabled vehicles.
- Plowed snow.
- Speed changes for turning vehicles.

Attitudes pertaining to the use of shoulders as pedestrian facilities differ. One view is that shoulders are adequate for pedestrian use, while other sources consider shoulders as a last resort for pedestrian accommodation. While the 1998 *Statewide Bicycle and Pedestrian Master Plan* from Louisiana states, " For the pedestrian, a paved shoulder can offer a safe route away from the path of motorists along an otherwise hazardous road," the 1998 ITE *Design and Safety of Pedestrian Facilities* states, "In extreme cases, a roadway shoulder can also provide a safer pedestrian accommodation than walking in the travel lanes themselves." (*32,34*)

However, throughout the literature it is clear that shoulders are no substitute for sidewalks or walkways.

Whether people are using the shoulder as a means of transportation to or from a destination or as a means of physical activity when a sidewalk is not present, it is to be discouraged. Approximately 15 percent of pedestrian collisions in rural and suburban areas occur when a pedestrian is struck walking along a roadway. (*32*)

A shoulder facility is not appropriate for the elderly, the disabled, or children. (*37*) The ADAAG does not apply to the pedestrian use of shoulders. The Vermont State Roadway Design Standards state that it is legally unnecessary to design shoulders for the use of disabled pedestrians but it is recommended that this consideration be made where possible. (*42*)

Guidelines to Consider Shoulders for Pedestrian Accommodation

In the design of shoulders, pedestrians should always be a consideration. Even where pedestrian use is discouraged, shoulders are the route in which pedestrians leave and return to disabled vehicles (*32*).

A safe route to walk along public right of ways should be provided where such a demand exists. In areas where sidewalks or walkways are not warranted, paved or unpaved shoulders can be utilized for pedestrian accommodation. However, a separated sidewalk or walkway is preferable.

According to the 1990 AASHTO green book currently there are no standard warrants for the necessity of sidewalks on highways. The assessment should be dependent on the pedestrian and vehicle volumes, the vehicle speeds, and their relative timing. (*43*) In rural areas if pedestrian use is heavy or there are concentrated residential or commercial development, sidewalks are warranted.

Shoulders are suited for light pedestrian use in some rural or suburban areas. The December 1998 *State of Vermont Agency of Transportation Bicycle and Pedestrian Plan* documents a standard that paved shoulders should be provided on all principal and minor arterials and major collectors to improve bicycle and pedestrian safety. (*44*)

Shoulder Widths

A typical minimum shoulder width to support pedestrian activity is 1.2m (4ft). This dimension is set to accommodate light pedestrian volumes on roadways without high vehicle speeds. With more pedestrian traffic or higher vehicle speeds, wider sections should be considered.

Standards presented in the Louisiana *Statewide Bicycle and Pedestrian Plan* state where pedestrian use is expected to be light on rural roads, a 1.2m (4ft) paved

shoulder is sufficient. (*34*) Paved shoulders of less than 1.2m (4ft) may be used where the Average Annual Daily Traffic (AADT) is less than 1200 and pedestrian use is only occasional. The decision to use widths less than 1.2m (4ft) should be based on motorized and non-motorized traffic flows, highway geometries, and collision data, although no specific criteria is specified. Widths greater than 1.2m (4ft) should be considered when any of the following apply:

- Vehicle speeds are greater than 48km/h (30mph).
- AADT is greater than 2000 vehicles.
- Trucks, buses and RV's contribute to more than 5% of the traffic.
- Bicycle use is expected occasionally.
- Pedestrian trip generators exist within three miles.
- Pedestrians are expected to travel in groups.

A 2.4m to 3.0m (8ft to 10ft) shoulder is suitable for high-speed suburban arterial state highways according to the *Louisiana Statewide Bicycle and Pedestrian Plan*. (*34*)

The April 1996 New Jersey Department of Transportation *Pedestrian Compatible Planning and Design Guidelines* outlines very similar standards—the exception is that to consider a larger shoulder width the vehicle speeds should be over 65km/h (40mph). (*38*)

The standards listed in the *Oregon Bicycle and Pedestrian Plan*, Table 3-8, are identical to the guidelines listed in the AASHTO *Geometric Design of Highways and Streets* (1990) for the widths of a usable shoulder for rural arterials, rural collectors, and rural local road. (*36,43*)

Table 3-8: Standard Rural Highway Shoulder Widths

	ADT under 250	ADT 250-400	ADT 400-DHV*100	DHV 100-200	DHV 200-400	DHV over 400
Rural Arterials	1.2m (4ft)	1.2m (4ft)	1.8m (6ft)	1.8m (6ft)	2.4m (8ft)	2.4m (8ft)
Rural Collectors	0.6m (2ft)	0.6m (2ft)	1.2m (4ft)	1.8m (6ft)	2.4m (8ft)	2.4m (8ft)
Rural Local Route	0.6m (2ft)	0.6m (2ft)	1.2m (4ft)	1.8m (6ft)	1.8m (6ft)	2.4m (8ft)

**DHV (Design Hourly Volume) is the expected traffic volume in the peak design hour (usually at commuter times); usually about 10% of Average Daily Traffic (ADT) in urban areas, higher on rural highways with high recreational use (beach access, ski resorts, etc.)*

SOURCE: Oregon Bicycle and Pedestrian Plan 1995

Shoulder Delineation

Shoulders used as pedestrian facilities must be visible by drivers. In the 1990 green book, AASHTO suggested that shoulders should differ in color and texture from the travel lanes. The purpose is to make shoulders more recognizable at night and in foul weather by sight and roughness and to discourage vehicular use as an additional lane. For concrete surfaces bituminous, crushed stone, gravel, and turf shoulders can be appropriate options. For asphalt pavements turf and various aggregates may be considered. (*43*)

Following the guidelines of the 1988 Manual on Uniform Traffic Control Devices, a 10cm to 15cm (4in to 6in) white line, for the pavement edge stripe will decrease the necessity for the contrasting colors and textures. (*45*)

The 1997 Washington State Department of Pedestrian Facilities Guidebook suggests the possible use of nonstandard markings for delineation; such as an extra wide fog line, dashed stripe, angled stripe or other method. (*31*)

Raised pavement markers are not usually suitable for this use because of the possible adverse effects for bicyclists. (*31*)

Shared Pedestrian and Bicycle Use of Shoulder

While sources commonly state that the shoulder should be wide enough for both pedestrians and bicycles; the *Pedestrian Facilities Guidebook (WSDOT)* states that the use as a combined bicycle and pedestrian facility is not recommended unless designed as multi-use trail in accordance with local, state and federal standards. (*31*)

However, *Pedestrian Facility Guidelines (references ADAAG), Vermont State Roadway Design Standards, Pedestrian Compatible Planning and Design Guidelines (NJDOT), Priorities and Guidelines for Providing Places for Pedestrians to Walk Along Streets and Highways* and *Oregon Bicycle and Pedestrian Plan* all mention that the shoulder should be of sufficient width for pedestrian and bicycle use. (*35,36,38,42,46*) *AASHTO Geometric Design of Highways and Streets (1990)* cites that shoulders can accommodate both bicycles and the occasional pedestrians. (*43*)

Potential Obstacles

The *Louisiana Statewide Bicycle and Pedestrian Master Plan* maintains that state highway shoulders should remain consistent in width through intersections and not be used as a right turning lane. If an appropriate width cannot be maintained in a pedestrian use area, a separated path is required. The shoulder quality should be comparable to the roadway and the slope of the road should be continued through the shoulder. Obstacles such as manhole covers, rumble strips, and drainage grates should be avoided where possible and extra shoulder width should be considered where they exist. (*34*)

Parking restrictions should be established and enforced where pedestrians use shoulders. (*31*)

Paved and Unpaved Shoulders

Shoulders may be paved or unpaved surfaces. Unpaved shoulders of gravel or crushed rock should be well compacted to be more easily traverse by walkers. Compacted earth and grass shoulders may create unfavorable conditions in wet weather.

The 1997 *Vermont State Roadway Design Standards* state the portion of the shoulder necessary for bicycle use is the only section that must be paved. (*42*)

Trails and Pathways

Trails and pathways typically have an independent alignment from roadways. Trails are used for recreation purposes, as school routes, by commuters and for other utility trips. Pedestrian trails are limited to use by pedestrians, which often includes

walkers, skaters, and wheelchair users. Shared use trails, also referred to as multi-use trails, additionally accommodate equestrians and bicyclists as well as pedestrian traffic.

Trails should not be a replacement for pedestrian facilities along a roadway. Well-planned trails can be an auxiliary option for linkage between selected locations within a community.

Recreation Trails

Recreation trails in parks or in open spaces are often rated by the level of accessibility. The standard ratings are easy, moderate, and difficult. Easy is designated by a circular symbol and consist of a paved surface with at least a 1.2 m (4 ft) clear with relatively gentle slopes. Moderate trails are designated by a square symbol and must be constructed by a type of compacted material. A diamond is used as the symbol for difficult trails and has greatest allowable slopes. Table 3-9: Design Guidelines for Recreation Trails shows design parameters for each of the three levels of accessibility. (*31*)

Shared Use Trails

Safety is a concern for shared use trails. Trail designs should include the following measures to reduce potential hazards to the users:

- Adequate vertical and horizontal sight distances to accommodate both pedestrians and bicyclists.
- Wide shoulders to allow passing and resting.
- Speed limits for bicyclists.
- Directional signing.
- Delineation for separation of modes.
- Optional centerline delineation.

Table 3-9: Design Guidelines for Recreation Trails

Design Guidelines for Recreational Trails

	Levels of Accessibility		
Design Element	***Easy***	***Moderate***	***Difficult***
Surfacing	Paved — Asphalt/ Concrete Boardwalk with ramped or level entry	Compacted crushed rock or compacted dry earth	Varies, but needs to be firm and stable
Clear width	1.2 m (48 in)	.9 m (36 in)	.7 m (28 in)
Sustained running slope	5 percent	8.3 percent	12.5 percent
Maximum grade	8.3 percent*	10 - 14 percent	20 percent
For a Maximum Distance of	9.1 m (30 ft)	15.2 m (50 ft)	15.2 m (50 ft)
Cross slope maximum	2 percent	3 percent	5 percent
Passing space interval	61 m (200 ft) maximum	91 m (300 ft) maximum	122 m (400 ft) maximum
Rest area interval	122 m (400 ft) maximum	274 m (900 ft) maximum	366 m (1,200 ft) maximum
Small level changes	1.3 cm (0.5 in) maximum	2.6 cm (1 in) maximum	7.6 cm (3 in) maximum

** If the pathway is designated as an accessible route of travel on the site, handrails are required on both sides of the pathway wherever the grade exceeds 5 percent.*

Source: Adapted from Universal Access to Outdoor Recreation. A Design Guide

SOURCE: *Pedestrian Facilities Guidelines*

Shared use trails should preferably not be located adjacent to roadways. Bicyclists will be forced to travel in the opposite direction of vehicles against accepted practices. Motorist at intersections and driveways are not accustomed to searching for bicycles approaching from the alternate direction.

Where no feasible alternative exists to a shared use trail adjacent to the roadway a lateral separation of at least 1.5 m (5 ft) should exist. Landscaping, drainage ditches, or a concrete barrier are options for separation.

Trail Dimensions

Table 3-10: Recommended Dimensions for Trails and Pathways lists dimensions for the width of various types of paths, separation from the roadway, shoulders, and lateral clearance. The table appears in *Pedestrian Facility Guidelines.* (*31*)

Table 3-10: Design Guidelines for Recreation Trails

Recommended Dimensions for Trails and Pathways

Trail/Pathway Element	*Recommended Dimensions*			*Comments*
Multi Use Pathway Width (two way, shared with bicyclists)	3.0 m 3.7 m 4.3 m	(10 ft) (12 ft) (14 ft)	minimum desirable optimum	Minimum width should only be used where volumes are low and sight distances are good; width should be based on relative speed of users; higher speed users (bicyclists and skaters) require greater widths.
Roadway Separation	1.5 m	(5 ft)	minimum	Minimum separation for parallel, adjacent path; a physical barrier should be installed where minimum separation cannot be met.
Shoulders	.3 m .6 m	(1 ft) (2 ft)	minimum (peds only) minimum (multi use)	Shoulders provide pull-off/resting and passing space; should be graded to the same slope as the path; minimum shoulder width of 0.3 m (1 ft) should only be used in constrained areas.
Additional Lateral Clearance Each Side of Shoulder	.3 m .6 m	(1 ft) (2 ft)	minimum* desirable*	Lateral clearance is necessary for safe operation on either side of a multi use path; should be graded to the same slope as the path.
Vertical Clearance	2.4 m 3.0 m	(8 ft) (10 ft)	minimum desirable	Necessary for good visibility and clearance for bikes/horses on multi-use pathways.
Paved Pedestrian Only Path Width	1.5 m 1.8 m	(5 ft) (6 ft)	minimum desirable	These pathways are for exclusive use by pedestrians (see Figure 34).
Unpaved Pedestrian Only Path Width	.6 m 1.2 1.8 m	(2 ft) (4 6 ft)	minimum desirable	Best as limited purpose facility in rural or semi-primitive areas; can provide interim solution (see Figure 35); minimum width should only be used in constrained areas.
Multi-Use Unpaved Path Width	1.8 m 2.4 3.0 m	(6 ft) (8 10 ft)	minimum desirable	Only suggested as an interim solution and not appropriate for high use trails; best in rural or semi-primitive areas (see Figure 36).
Pedestrian Mall/ Corridor (Urban) Width	3.0 m 3.7 m 4.6 m	(10 ft) (12 ft) (15 ft)	minimum desirable optimum	Pathways in urban areas or those that receive heavy use should be wide enough to accommodate several people walking side-by-side or groups of people walking in opposite directions.

SOURCE: *Pedestrian Facilities Guidebook*

PEDESTRIAN GRADE – SEPARATED CROSSINGS

A pedestrian grade-separated crossing is a physical separation of the vehicular traffic and pedestrians by means of elevation or depression of the pedestrian walkway in contrast with the vehicle's travel way. Pedestrian grade-separated crossings can improve pedestrian safety, increase highway capacity, reduce traffic collisions, and lessen delays for both pedestrians and vehicles when designed and located properly.

Pedestrian Resistance to Separated Structures

A grade separation facility must be convenient; pedestrians will not use a facility only for the added safety benefits. It should be located in approximately the same path a pedestrian would choose at-grade. Pedestrians will be less likely to utilize a route that lengthens their journey or significantly increases the change in elevation experienced. The ADA restricts the maximum grade on approach ramps and this may necessitate a long incline that could discourage users.

When there are occasions where adequate traffic gaps exist for pedestrians to cross at-grade, they often choose to do so. Grade separated pedestrian facilities should only be employed where at-grade crossing cannot occur; for example at freeways, major highways, waterways, or railroads. (*39*)

A study by Moore and Older found that approximately 95% of pedestrians would use an overpass if the time it takes to use the facility and to cross at-grade were approximately the same. However, if the time taken to use the over-crossing is 1 ½ times that of the at-grade crossing, almost no one will choose to use the overpass structure. The rates at which people were willing to use an under-crossing were even smaller because under-crossings are often perceived as unsafe due to concerns of crime. (*47*) To encourage use of a tunnel, the openings should be wide enough to increase natural lighting and the length should be as short as possible. (*31*)

Methods to reduce the appearance of elevation changes may be useful in convincing pedestrians to use the facility. Earthen berms or structure improvements could be used for this purpose. (*34*)

An added risk is encountered when a facility exists but pedestrians choose not to use it. Particularly because motorists are not expecting the crossing pedestrians and appropriate at-grade crossing facilities are not present. For the facility to remain effective it must be properly maintained.

Fences, medians, railings, and barriers may be necessary to prevent crossing at-grade. Regulation signs prohibiting at-grade crossing can also be posted. School crossing areas may necessitate adult supervision to ensure children use the structure.

Warrants for Grade-Separated Structure

A study by Zeeger and Zeeger found that state and local agencies consider grade-separated structures to be most appropriate for pedestrian crossings where there is a clear pedestrian origin and destination and one of the following circumstances exists (*31,32*):

- There is a moderate to high demand for pedestrians to cross a freeway or expressway.
- There are a large number of children crossing a high-speed or high-volume roadway.
- There are large pedestrian and vehicle volumes and very hazardous crossing conditions (for example wide roadways with high speeds or poor sight distance.)

Pedestrian grade separations have typically been around universities, industrial plants, government buildings, major shopping centers, large hospitals, recreation facilities and other major pedestrian generators. (*48*)

The following are specific warrants for a grade-separated crossing developed by E. A. Axler in the 1984 report *Warrants for Pedestrian Over and Underpasses*: (*31,32*)

- For the continuous four hours of peak pedestrian travel times, pedestrian volumes must be greater than 300 per hour if the vehicle speed is over 40mph, in an urban area, and not crossing a freeway. For other circumstances, the pedestrian volumes must only be above 100 per hour for the continuous four hours of peak pedestrian travel times.
- When using the pedestrian volume warrant above and the vehicle speeds are greater than 65 km/h (40mph) and the site is in a urban area, the vehicle volume should be at least 10,000 for the same four hour period established in the pedestrian volume warrant or have an ADT greater than 35,000. When using the pedestrian volume warrant and the vehicle speeds are not greater than 65 km/h (40mph) or the site is not in an urban area, the vehicle volume should be at least 7,500 for the same four hour period established in the pedestrian volume warrant or have an ADT greater than 25,000.
- A proposed facility must be located more than 600 feet away from an existing safe crossing. (A safe crossing being defined as signalized crossing with timing sufficient for pedestrian use or other grade separated crossing.)
- Barriers should be used to restrict crossing at-grade where a structure exists.
- Lighting should be provided to discourage potential crime. It may be necessary to light underpasses at all times and overpasses strictly at night.
- Elevation change is a factor that must be considered to reduce the cost of the structure and for the convenience of the users.
- A new development may create a need for an overpass or underpass. The area that creates the pedestrian activity should have "direct access" to the facility.
- Funding must be available before there is a commitment to proceed with a grade-separated structure.

The following table appears in the 1996 *Pedestrian Compatible Planning and Design Guidelines* from the New Jersey Department of Transportation (NJDOT). (*38*) It is a summary of the volume warrants listed by Axler in the 1984 report *Warrants for*

Pedestrian Over and Underpasses. It is stated that these warrants are appropriate in cases of new roadway construction in which the roadway grade can be designed to ease the expense and construction of the grade-separated facilities. According to the 1996 *Pedestrian Compatible Planning and Design Guidelines* (NJDOT) these warrants do not apply to existing roadways or new construction if substantial grade work must be completed.

The columns of Table 3-11 establish warrants for the construction of pedestrian crossing structures. To meet the warrant both the pedestrian volume and vehicle volume should be greater than the table value. It is stated that if one volume is slightly less than the table value while the other is substantially greater, a separated structure may be warranted. It is not clear from the 1996 *Pedestrian Compatible Planning and Design Guidelines* (NJDOT) if both vehicle volumes must be met. However, referring to Axler's warrants, either of the vehicle volumes can be satisfied to warrant a pedestrian grade separated structure.

Table 3-11: Vehicle and Pedestrian Volume Warrants for Construction of Pedestrian Crossing Structures

Facility	Pedestrian Volume (Total for 4 Hours)	Vehicular Volume (Same 4 Hours)	Vehicular Volume (AADT)
Freeway	100	7,500	25,000
Arterial	300	10,000	35,000

SOURCE: 1996 *Pedestrian Compatible Planning and Design Guidelines (New Jersey DOT)*

The 1998 *Louisiana Statewide Bicycle and Pedestrian Master Plan* references the 1996 *Pedestrian Compatible Planning and Design Guidelines* (NJDOT) and includes the same table, Table 3-11, with an alternate title—"Volume Levels that Necessitate Installation of Over/Underpasses," and does not state that these warrants on Table 3-11 are for new roadway construction projects. (*34*)

The City of San Diego has separate criteria to warrant a pedestrian overpass at both unsignalized intersection and signalized intersections. Current San Diego practice does not allow under-crossings. Table 3-12 is the minimum requirements to a warrant a crossing facility. In addition to the minimum warrants listed in Table 3-12 for the unsignalized intersection, an economic analysis must indicate that a pedestrian over-crossing will be less expensive than a traffic signal for a ten-year period. (*48*)

Table 3-12: Minimum Warrants for Overpass Structure

Intersection Type	Major Street Volume (continuous 4 Hour Period) Vehicles	Pedestrians	Major Street Daily Volume Vehicles	85th Percentile Speed	Street Width
Unsignalized	3000	300*	–	>30 mph	–
Signalized	–	100	35000	–	78ft
* Children under the age of 12 are counted as the equivalent of 2.5 pedestrians.					

SOURCE: City of San Diego

An alternate route should be available anytime that an evaluation has concluded that at-grade crossings should be prohibited for safety reasons. A grade separated crossing facility may be warranted as an alternative route in this situation.

Generally a new facility should not be considered in a location in which a safe crossing route exists within 180m (600ft)—such as a signalized intersection, mid-block crossing, or another grade separated facility. An exception is when the warrants for a structure are greatly exceeded. (*38*)

Evaluation Variables and Costs

Costs and benefits must be carefully weighed. Even when a grade-separated crossing structure may be warranted by the criteria above, careful evaluation must be taken because of the high associated costs. Table 3-13 lists the variables that must be considered.

Table 3-13: Pedestrian Facility Evaluation Variables

Pedestrian Transportation	1) Travel Time 2) Ease of Walking 3) Convenience 4) Special Provision for Various Groups
Other Transportation	5) Motor Vehicle Travel Costs 6) Use of Automobiles 7) Impact on Existing Transportation Systems 8) Adaptability to Future Transportation Development Plans
Safety	9) Societal Cost of Collisions 10) Collision Threat Concern 11) Crime 12) Emergency Access/Medical & Fire Prevention
Environment/ Community	13) Pedestrian- Oriented Environment 14) Effects of Air Pollution 15) Noise Impacts 16) Health Effects of Walking
Residential/ Community	17) Residential Dislocation 18) Community Pride and Cohesion 19) Community Activities 20) Aesthetic Impact, Compatibility with Neighborhood
Commercial/ Industrial Districts	21) Gross Retail Sales 22) Displacement, Replacement, or Renovation Required of Encouraged by Facility 23) Ease of Deliveries & Employee Commuting 24) Attractiveness of Area to Business
Urban Planning	25) Adaptability to Future Urban Development Plans 26) Net Change on Tax Receipts and Other Revenue 27) Public Participation in the Planning Process

SOURCE: *Design and Safety of Pedestrian Facilities*

Table 3-14 contains the possible cost categories related to the planning, construction, maintenance, and operation of such a facility.

Table 3-14: Major Cost Components of Pedestrian Facilities

1) Design and architect costs	
2) Financing costs and legal fees	
3) Site preparation	Real estate acquisition Demolition Drainage Grading Utilities relocations Foundations Required Permits
4) Construction	Height, width, and length of facility Length of span (if any) Method of support Enclosures (if any) Materials Walkway paving, curbs
5) Finishing touches	Lighting Street furniture Amenities Landscaping
6) Operation and maintenance	Cleaning Gardening Maintenance and repairs Lighting Security Taxes Insurance

SOURCE: Design and Safety of Pedestrian Facilities

Accessibility for Disabled

Approach ramps must be provided for over-crossings and under-crossings and must be consistent with the ADA requirements. The restricted maximum grade of 5% may necessitate a long ramp. Stairs may be used in parallel with a ramp but not exclusively.

Pedestrian Overpasses versus Underpasses

The geometrics of the roadway may dictate which type of structure; an overpass or underpass is more feasible. In locations where a roadway is sunken, an overpass may not need a large elevation change to meet the vertical clearance requirements and would be the natural choice. While at other locations a raised roadway would facilitate an under-crossing more easily and economically.

Overpasses are more common because of concerns regarding under-crossings relating to crime, vandalism, drainage, high water tables, relocation of utilities, and higher construction costs. Overpasses have a greater vertical clearance requirement

and when spanning US Interstate Highways, they must meet military guidelines for vertical clearances. The height of these structures can require lengthy ramps in compliance with ADA standard and may demand extended right-of-ways.

Overpasses are easier to maintain and supervise. Fencing should be provided to prevent objects from being thrown off the structure into the roadway. At night the facility should be well lit.

Underpasses are sometimes needed to connect the pedestrian route to an underground parking garage or shopping center or in places where an elevated roadway exists. The perception that under-crossings are unsafe due to crime should also be considered. Underpasses should always be well lit and clear of debris and graffiti.

In the City of San Diego all the existing pedestrian tunnels, four in total, have been taken out of service because of problems including crime, public nuisance, and general negative public reaction. No others are anticipated. (29—Policy No. 200-07) All grade separated pedestrian crossing structures in San Diego are over-crossings.

Design Elements

The projected pedestrian volumes or the shared use requirements for bicycles and pedestrians, where this is the intended use, should determine the walkway minimum widths. Because accessibility requirements necessitate ramps for separated structures, it must be assumed that the travel way will be shared by bicycles and pedestrians. A typical suggested minimum walkway width is 3.7m (12ft). This is required for structures in which maintenance or emergency vehicles must pass. (*31*)

The 1998 *Louisiana Statewide Bicycle and Pedestrian Master Plan* relates the width requirements of under-crossings to the length of the structure. Under-crossings up to 17m (56ft) in length should have a minimum width of 4.3m (14ft). For lengths from 17-29.3m (56-96ft), a 4:1 length to width ratio should be used. For over-crossings, the width should preferably be 4.3m (14ft) but only 2.4m (8ft) is required for Louisiana. If the pedestrian volume is expected to exceed 280 people per minute on either an over or under-crossing, then a design capacity of 20 persons-per-foot width guideline should be employed as long as it exceeds the above requirements. (*34*)

Other minimum width recommendations include 2.4m (8ft) for New Jersey and Oregon requires a 0.6m (2ft) increase to the approach walkway's width for the span of the structure. (*36,38*)

The ramps with grades between 6.25-8.33% require a level resting platform at least every 9.1m (30ft) while grades between 5-6.25% require a level resting platform at least every 12.2m (40ft). At locations where the walkway changes direction, a 1.5m (5ft) area is necessary. Passing areas are required at least every 60m (200ft) when the walkway does not maintain a minimum width of 1.5m (5ft). Any ramp with a vertical change greater than 0.15m (6in) requires a handrail with a height between 290-320mm (34-36in). The handrail must extend 0.3m (1ft) into the level resting platform. (*49*)

Railings should be provided on shared-use crossings with a minimum height of 1.1m (3.5ft). Openings in the barrier should be no greater than 150mm (6in).

Common over-crossing vertical clearances range from 5.2-6.7m (17-22ft) above a roadway. The length of the ramp and number of landing areas per ramp will be dependent on the total vertical rise of the structure.

In the case of underpasses, a typical minimum requirement for vertical clearance is 8ft. A height of 3m (10ft) is preferable and necessary if vehicles will enter for maintenance or for emergency purposes. (*34*)

Design elements to be avoided include blind corners, areas that cannot be reached by sweepers or power equipment, and regions that will require hand maintenance. (*36*)

Railings of 1.4m (4.5ft) are required on both sides of the over-crossings and when located near a school, overhead fencing is recommended. (*31*)

For under-crossings, security concerns can be reduced with added vertical and horizontal clearances. Additionally, natural light allowed in by roof openings in the day, designs without hidden areas caused by changing direction of path, and artificial lighting provided at levels of at least 108 lux (10 foot-candles) are worthy of consideration.

Practices that reduce graffiti such as murals or glazing should be used. Implementation of monitored video surveillance cameras can create a safer environment and community activities in the area tend to discourage crime and unwanted use. (*37*)

The *Pedestrian Facility Guidebook* (WSDOT) states that when entering a tunnel, alignment must allow the pedestrian a clear view of the other end. This can be accomplished by raising the roadway in the mid-section to reduce the necessary overall elevation change for the underpass. (*31*)

Alternatives

Grade-separated crossings are expensive. Alternatives methods must always be considered first. A pedestrian refuge island may be appropriate when the large width of a roadway is the problem. Pedestrian signals may be timed for the crossing of only half of the roadway to create less interference with vehicular traffic at wide intersections. (*34*)

If a need exists for a pedestrian crossing, the need for a grade separated vehicle crossing may also exist. A grade-separated vehicle separation would additionally benefit pedestrians by adding to the perception of safety and may be a better link to the street network. (*34*)

The possibility of widening existing structures must also be examined. Examples of widening stream crossings and railroad crossings to accommodate pedestrians are documented in the Louisiana *Statewide Bicycle and Pedestrian Master Plan.*

Busing in school areas or channeling the pedestrians to another crossing area may also be adequate approach to pedestrian crossing problems. (*50*)

CROSSINGS AND INTERSECTIONS

Number of Collisions at Junctions

The number of collisions at intersection locations is attributed to human limitations and the complexities pedestrians encounter when attempting to cross motorized traffic. Difficulties for crossing pedestrians include judgment errors in

traffic gaps, insufficient visual searches, lack of attention to surroundings, inappropriate expectations of the environment, and rushed behavior. (*52*)

Intended Purpose of Crosswalks

Marked crosswalks at signalized and unsignalized intersections serve the main purpose of channelizing pedestrians to an appropriate crossing path. Crosswalk markings at mid-block locations, in addition, legally define a crosswalk. The *Manual on Uniform Traffic Control Devices* (MUTCD) states that crosswalks warn motorists of pedestrian crossing locations. In reality, crosswalks are much more visible to pedestrians and have little if any warning effect to approaching motorists. (*45*)

The legal definition of a crosswalk includes both marked and unmarked crosswalks. An unmarked crosswalk, which extends the pedestrian traveled way from the sidewalk across a street, occurs at all intersections except at alleys or where a posted regulatory sign prohibits crossing. (*53*)

Safety Perceptions and Concerns

Attitudes concerning the action of marking crosswalks have changed over the years. In the 1950's and 1960's it was assumed that marking crosswalks was a pedestrian feature that increased safety and were placed indiscriminately. (*32,37*)

Studies since have had mixed findings. Pedestrians are more likely to cross within the marked crosswalks, however, safety may actually be reduced in marked crosswalks at unsignalized intersections. The markings may create a false sense of security for the pedestrian with pedestrians sometimes incorrectly expecting vehicles to act more cautiously. Crosswalks are much more visible to pedestrians than to motorists due to speed and distance. (*32,37*)

Another more recent study has found that marked crosswalks were as safe or safer in all situations examined. (*37*)

In current practice, marked crosswalks are assumed to be most appropriate at signalized intersections in urban areas and where pedestrian indication signals exist. When marked crosswalks are located indiscriminately, their effectiveness can be compromised. Motorists may become less aware of their presence. (*31*)

Some safety concerns related to marked and unmarked crosswalks include:

- Approaching drivers may not notice crosswalks.
- Crossing gaps for pedestrians at times are inadequate.
- Stopped or parked vehicles or other obstacles can obscure pedestrians from the view of motorists.
- Approaching drivers may be unwilling to yield for pedestrians.
- Marked crosswalks and pedestrians can be difficult to see at night.

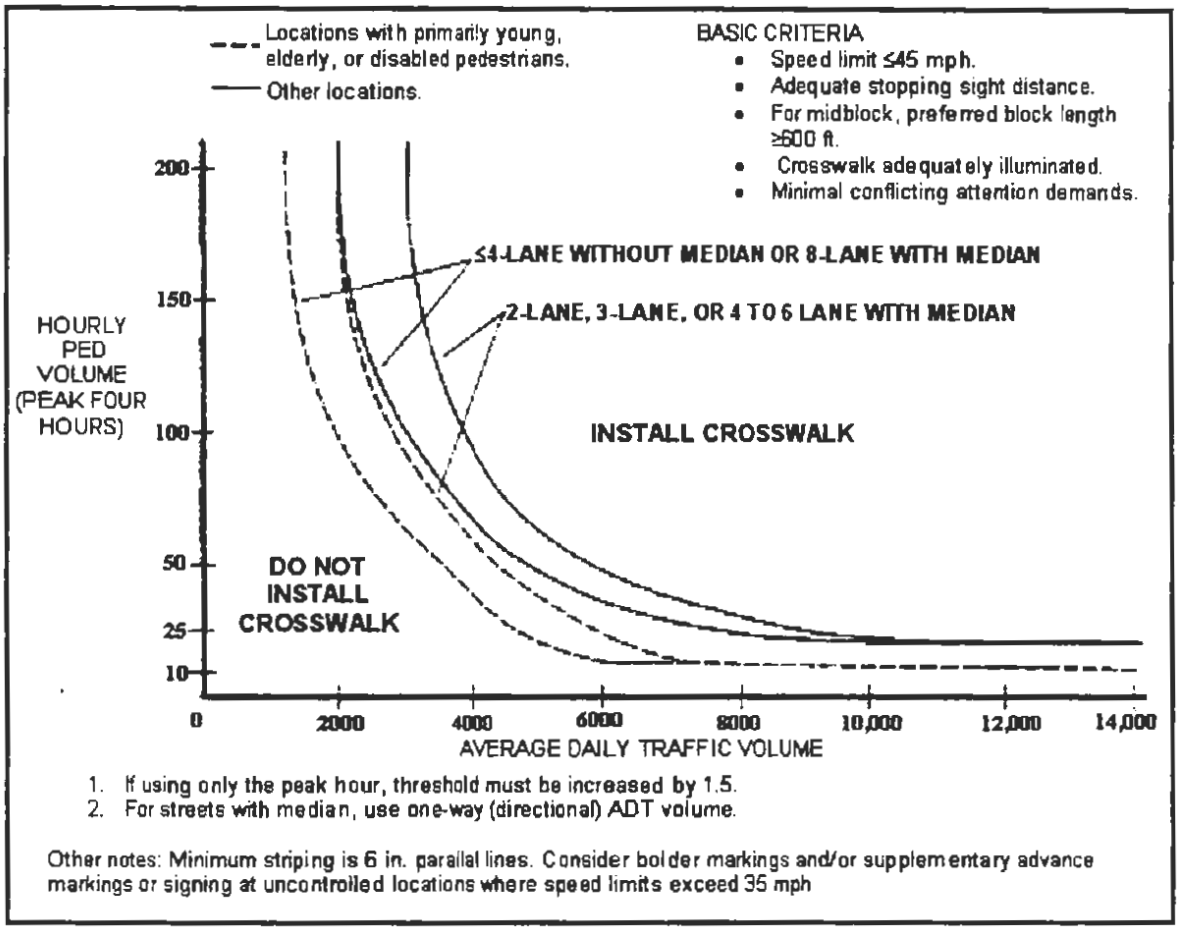
Appropriate Locations for Marked Crosswalks

There is no accepted set of warrants for marking crosswalks. It is common to stripe crosswalks in downtown areas and around schools. Considerations for the placement of a marked crosswalk include present and anticipated land use, sight distance, and the presence of young, disabled, or elderly pedestrians.

The final decisions where to place a marked crosswalk should be based on an engineering study of the specific location. No set of standards can fit all locations or

ensure an increase in safety. Crosswalk placements also should take into account the location of the curb ramps. Wheelchair users should not have to leave a marked crossing area to access the ramp.

Figure 3-2 is included in the 1999 *Florida Pedestrian Planning and Design Handbook*, 1997 *Pedestrian Facilities Guidebook*, and 1998 *Design and Safety of Pedestrian Facilities* and first appeared in the 1987 article by Steven A. Smith and Richard L. Knoblacuch, *Guidelines for the Installation of Crosswalk Markings*. This figure illustrates criteria for installation of a marked crosswalk at uncontrolled intersections and mid-block locations including hourly pedestrian volumes, ADT volumes, number of lanes, and the general condition of pedestrians (i.e. young, elderly or disabled versus average ability). (*31,32,37*)



SOURCE: 1998 Design and Safety of Pedestrian Facilities

Figure 3-2: Guidelines for the Installation of Crosswalk Markings

The 1998 ITE publication, *Design and Safety of Pedestrian Facilities*, lists the following conditions in which marked crosswalks are generally recommended:

- Where a signalized intersection exists with either pedestrian signal indications or substantial pedestrian traffic.
- Where it will channelize or concentrate multiple crossing paths into one.

- Where it is necessary to guide pedestrians to the most suitable crossing location due to confusing geometrics or traffic maneuvers.
- Where approved school crossings exist or on recommended safe school routes.
- Where locations exist with significant pedestrian crossing and vehicle/pedestrian conflict.

Pedestrians will tend to use the most direct path. This will often mean pedestrians will choose to cross at locations with no traffic control when more convenient. Mid-block crosswalks should be considered where there is a clear demand for pedestrians to cross and no nearby existing crossing.

Mid-block crossings must only be located where a need has been determined. They must be clearly marked crosswalks and distinguishable by the pedestrians and motorists. Conditions in which a mid-block crossing should not be used (unless stop controlled) are as follows (*31*):

1. Streets with vehicle speeds over 72kph (45mph).
2. Downstream, and less than 91m (300ft) from a signalized intersection or bus stop.
3. Crossing point exists within 183m (600ft) except in districts where there is a defined need.

The 1999 Draft version of *Safety Effects of Marked VS Unmarked Crosswalks at Uncontrolled Crossing Locations* by Zeeger, Stewart, and Huang proposes guidelines for installation of a crosswalk and other pedestrian crossing safety improvements. Table 3-15 summarizes these recommendations. (*54*)

Table 3-15: Recommendations for Installing Marked Crosswalks at Unsignalized Locations

Recommendations for installing marked crosswalks and other needed pedestrian improvements at uncontrolled locations. *

Roadway Types	Vehicle ADT< 9,000			Vehicle ADT> 9,000 to 12,000			Vehicle ADT> 12,000 to 15,000			Vehicle ADT> 15,000		
	< 30 mph	35 mph	> 40 mph	< 30 mph	35 mph	> 40 mph	< 30 mph	35 mph	> 40 mph	< 30 mph	35 mph	> 40 mph
2-Lanes	C	C	C	C	C	C	C	C	X	C	X	X
3-Lanes	C	C	C	C	C	C	C	X	N	X	N	N
Multi-Lane (4 or more lanes)	C	C	C	C	C	C	X	X	N	X	N	N
With Raised Median												
Mulit-Lane (4 or more lanes)	C	C	C	C	X	X	X	N	N	N	N	N
Without Raised Median												

C = **Candidate sites for marked crosswalks.** Marked crosswalks must be installed carefully and selectively.

X = **May or may not need additional pedestrian crossing facilities in order to mark a crosswalk.** Pedestrian crash risk may increase if crosswalks are added without other pedestrian facility enhancements. Marked crosswalks at these locations should be closely monitored and removed, if necessary.

N = **Marked crosswalks are not recommended, since pedestrian crash risk may be increased with marked crosswalks.** Additional pedestrian facilities should be considered for these locations.

*These guidelines include intersection and mid-block locations with no traffic signals or stop sign on the approach to the crossing. They do not apply to school crossings. A two-way center turn lane is not considered a median. Crosswalks should not be installed at locations which could present an increased safety risk to pedestrians, such as where there is poor sight distance, complex or confusing designs, substantial volumes of heavy trucks, or other dangers, without first providing adequate design features and/or traffic control devices. Adding crosswalks alone will not make crossings safer. For an engineering study, a site review may be sufficient at some locations while a more in-depth study of pedestrian volumes, vehicle speeds, sight distance, vehicle mix, etc. may be needed at other sites. Whether marked crosswalks are installed, it is important to consider other pedestrian facility enhancements, as needed to improve the safety of the crossing (e.g., raised median, traffic signal, roadway narrowing, enhanced overhead lighting, traffic calming measures, curb extensions). These are general recommendations; good engineering judgment should be used in individual cases for deciding where to install crosswalks.

SOURCE: *Safety Effects of Marked Vs Unmarked Crosswalks at Uncontrolled Crossing Locations*

Generally, the recommendations by Knoblacuch and Smith, displayed in Figure 3-2, suggest that the practice of marking crosswalks should be considered as the vehicular traffic increases. (*32*) The work by Zeeger, Stewart, and Huang is in opposition to this finding. As Table 3-15 presents, Zeeger et al. recommend marking crosswalks at locations of lesser vehicular traffic. This recommendation of Zeeger et al. of installing marked crosswalks extends to most locations where the ADT is less than 12,000 per day. (*54*)

Studies have carefully correlated the presence of a marked crosswalk with increased pedestrian collisions. Two such studies of crosswalks in California are summarized here.

The *Evaluation of Marked and Unmarked Crosswalks at Intersections in California*, by Gibby et al. (*98*) states, "For unsignalized intersections, marked crosswalks clearly have a higher pedestrian accident rate." Their research applicable to signalized intersections was inconclusive.

A study of crosswalks and pedestrian safety for the city of Santa Ana, California found that 10% of the pedestrian collisions occurred at uncontrolled marked

crosswalks. A strong correlation between pedestrian collision frequency in the uncontrolled marked crosswalk and vehicular volumes was found. Ninety-four percent of all collisions occurred at locations with a volume above 6000 ADT. The study found that pedestrian volumes were not related to collision frequency in general. Pedestrian collision rates per crossing pedestrian were lower at locations with greater pedestrian crossing traffic at all vehicular volumes. It was stated that the "removal of crosswalks with high vehicle volume and low pedestrian volume offer a great potential for reduction of accidents." (*55*)

Crosswalk Design Factors

The 1998 *Portland Pedestrian Design Guide* lists a number of factors that should be addressed in a well-designed crosswalk. They are as follows (*36*):

- **Clarity:** It is apparent where to cross and where possible vehicle conflict points may occur.
- **Visibility:** The crosswalk allows visibility for both pedestrians and motorized traffic when the crossing is in use.
- **Appropriate Intervals:** The demand to cross and opportunities to do so are reasonably correlated.
- **Short Wait:** The wait experienced to cross by the pedestrian is reasonable.
- **Adequate Crossing Time:** The crossing time interval can accommodate pedestrians of all abilities or disabilities.
- **Limited Exposure:** Points of possible traffic conflicts are few and crossing distances are short.
- **Continuous Path:** The crosswalk approximately follows the pedestrians "natural" travel path.
- **Clear Crossing:** No barriers, obstacles, or hazards exist within the crosswalk.

Guidelines from the MUTCD concerning crosswalks have been summarized in Table 3-16.

Table 3-16 Recommended Guidelines for Crosswalk Design and Placement

MUTCD Crosswalk Requirement	Description
SHALL:	Have 150mm (6in) minimum width markings of solid white lines.
SHOULD:	Have 1.8m (6ft) minimum [3m (10ft) desirable crosswalk width.
	Be used where substantial pedestrian/vehicle conflicts exist.
	Be used at appropriate points of pedestrian concentration or where pedestrians could not otherwise recognize the proper place to cross (e.g., loading islands, midblock pedestrian crossings.)
	Not be used indiscriminately.
	Be installed based on an engineering study if located other than at a STOP sign or traffic signal.
	Have advance warning signs installed at midblock crossings where pedestrians are not expected, and allow for restriction of parking for adequate visibility.
MAY:	Be marked with white diagonal or longitudinal lines (parallel to vehicle traffic) for added visibility.
	Omit the transverse crosswalk lines when the extra diagonal or longitudinal markings are added. Use unique markings for diagonal crossings at signals when an appropriate exclusive pedestrian phase is used.

SOURCE: 1999 Florida Pedestrian Planning and Design Handbook

Width of Crosswalk Markings

The MUTCD suggests the minimum width of 150mm (6in) for the traditional horizontal bar crosswalk markings and 1.8m (6ft) for the crosswalk width.

Other sources, specifically 1999 *Florida Pedestrian Planning and Design Handbook*, the 1995 *Oregon Bicycle and Pedestrian Plan*, and the 1998 ITE *Design and Safety of Pedestrian Facilities*, recommend a minimum 3m (10ft) width for crosswalks and 250-300mm (10-12in) white horizontal borderlines due to operational concerns and installation costs. (*32,36,37*) For high pedestrian volumes or added visibility, even wider lines and crosswalk widths may be appropriate. ITE suggests 46-61cm (18-24in) lines should be used when greater emphasis is justified. (*32*)

High Visibility Crosswalk Markings

Several high visibility crosswalks in use are the zebra crossing (Figure 3-3a), ladder crossing (Figure 3-3d), piano crossing (Figure 3-3c), and the solid markings (Figure 3-3f). A dashed European style (Figure 3-3e) also captures attention because it is not commonly used. A side benefit is that the maintenance is also reduced over the traditional horizontal bars marking (Figure 3-3a) for the zebra, ladder, and piano. (*37*) The ladder and piano crosswalk markings can be deliberately aligned in such a way that the wear from vehicles' tires is minimized.

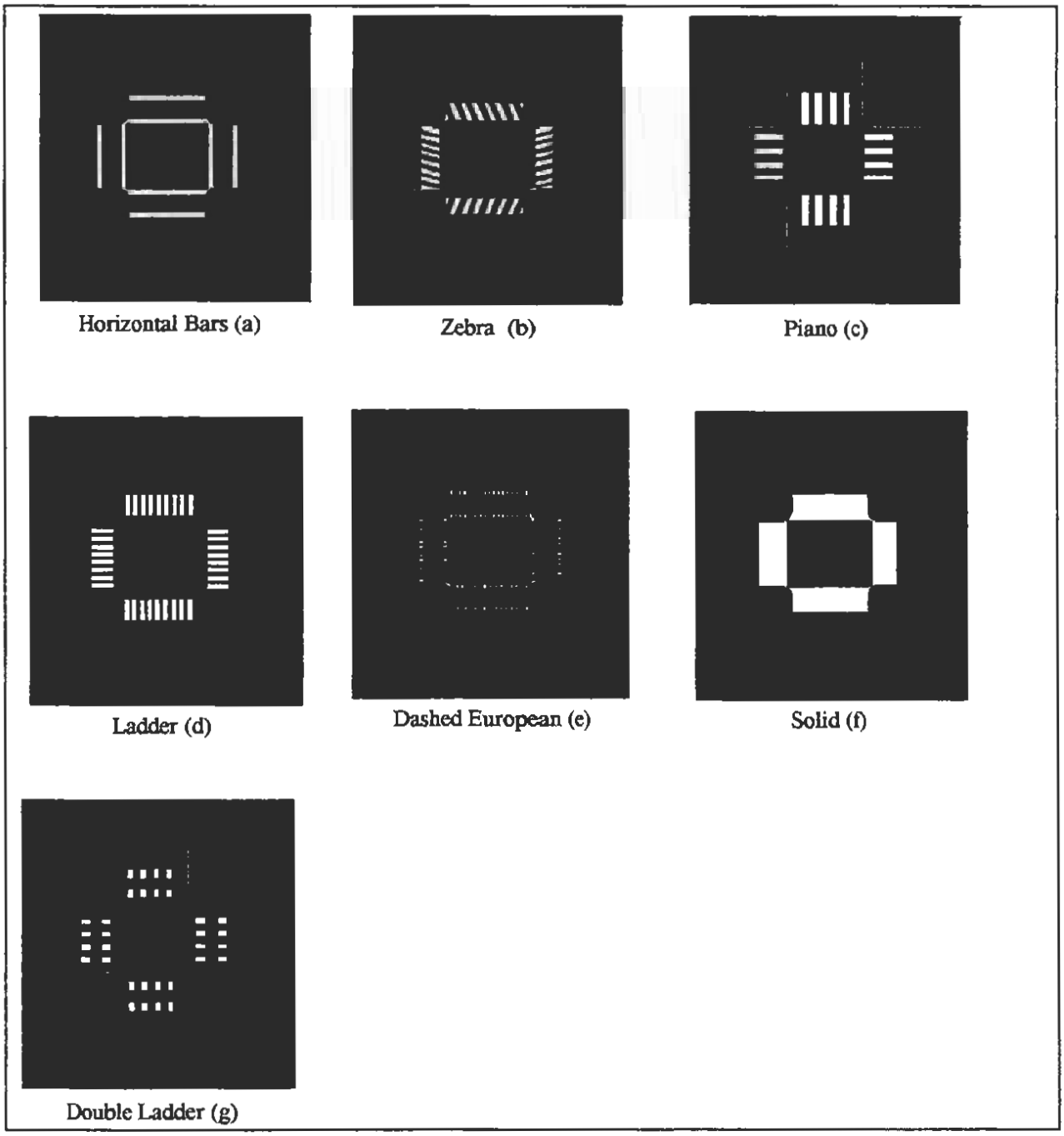
Currently there is debate over whether high visibility crosswalks should be reserved for limited locations such as schools or areas of heavy pedestrian traffic. This would help ensure that overuse does not make the markings less effective. Another point of view is that consistency in markings should be maintained. (*37*) Oregon Department of Transportation recommends the zebra crossing for added visibility and effectiveness without a discussion concerning overuse. (*36*)

The 1998 *Design and Safety of Pedestrian Facilities* suggests the use of high visibility markings should be reserved for locations where pedestrians may not be expected to cross, cross in high volumes, or when motorists may benefit from the added information. Such markings should not be used in locations where other traffic control devices exist or for all crosswalk markings. Indiscriminate use can reduce the overall effectiveness.

A recent Federal Highway Administration (FHWA) laboratory experiment found that a ladder design with a (12in) stripe and (24in) space was the optimal crosswalk pattern due to combination of cost considerations and laboratory results. However, there have been no conclusive collision studies and some agencies do not install high visibility crosswalk markings at any location.

There is a concern that high visibility crosswalks will increase the pedestrian's feeling of safety and may cause less cautious crossing behavior. (*32*)

Salt Lake City, Utah has begun using an alternate version of the ladder crosswalk. It is called the double ladder crosswalk (Figure 3-3g). It is identical to the traditional ladder version with the exception of the exclusion of the middle third of the striping. In wet and icy weather the crosswalk markings can become slippery for the pedestrians. The double crosswalk, while is visually the same to motorists as close as 46m (150ft), creates an unmarked, less slick section in the pedestrian travel path. (*56*)



SOURCE: *Pedestrian Facilities Guidebook*

Figure 3-3a-g: Crosswalk Markings

Limit lines

Stops lines encourage motorists to remain behind the pedestrian crossing area by a distance determined to be desirable. Distance between the vehicle and pedestrian crossing increases visibility for approaching vehicles, particularly in the case of smaller pedestrians and large stopped vehicles.

Limit lines may be positioned in front of the crosswalk and be white stripes between 0.3-0.6m (12-24in) wide. They should span all approach lanes and generally be located at least 1.2m (4ft) before the crosswalk. (*31*) The combination of a limit line and posting of a sign with an arrow at the limit line stating, "STOP HERE FOR PEDESTRIANS" may increase the effectiveness. (*57*)

The article "Safety Benefits of Advance Limit lines at Signalized Intersections: Results of a Field Evaluation," appearing in the September 2000 ITE Journal states that moving the limit lines from standard 1.2m (4ft) to 6m (20ft) in front of crosswalks decreases the number of motorists who enter the crosswalk during the pedestrian "WALK" and clearance phase. The additional distance between the limit line and pedestrian crossing also greatly increases the number of drivers who stop at least 1.2m (4ft) from the crosswalk which is the current standard.

A reduction of pedestrian collisions occurring when a stopped vehicle obscures a pedestrian from an approaching vehicle's vision would be expected with this treatment. An added benefit to the distanced limit lines is the possible reduction to right angle vehicle conflicts caused by vehicles running red lights. An increased time interval will occur before a waiting front vehicle enters the intersection. (*58*)

Raised Pavement Markers

Use of raised pavement markers (RPM) or reflectors for crosswalk delineation is not advised. The rumble effect will occur too late to be of adequate warning to motorists. Tripping or stumbling may result for people who walk at the edge of the crosswalk. Problems for bicycle and wheelchair users may also be created. The risk of snowplows dislodging RPM exists in the colder climates. RPM may be used upstream from a crosswalk, where the rumble effect may be useful, in combination with pedestrian crossing warning signs.

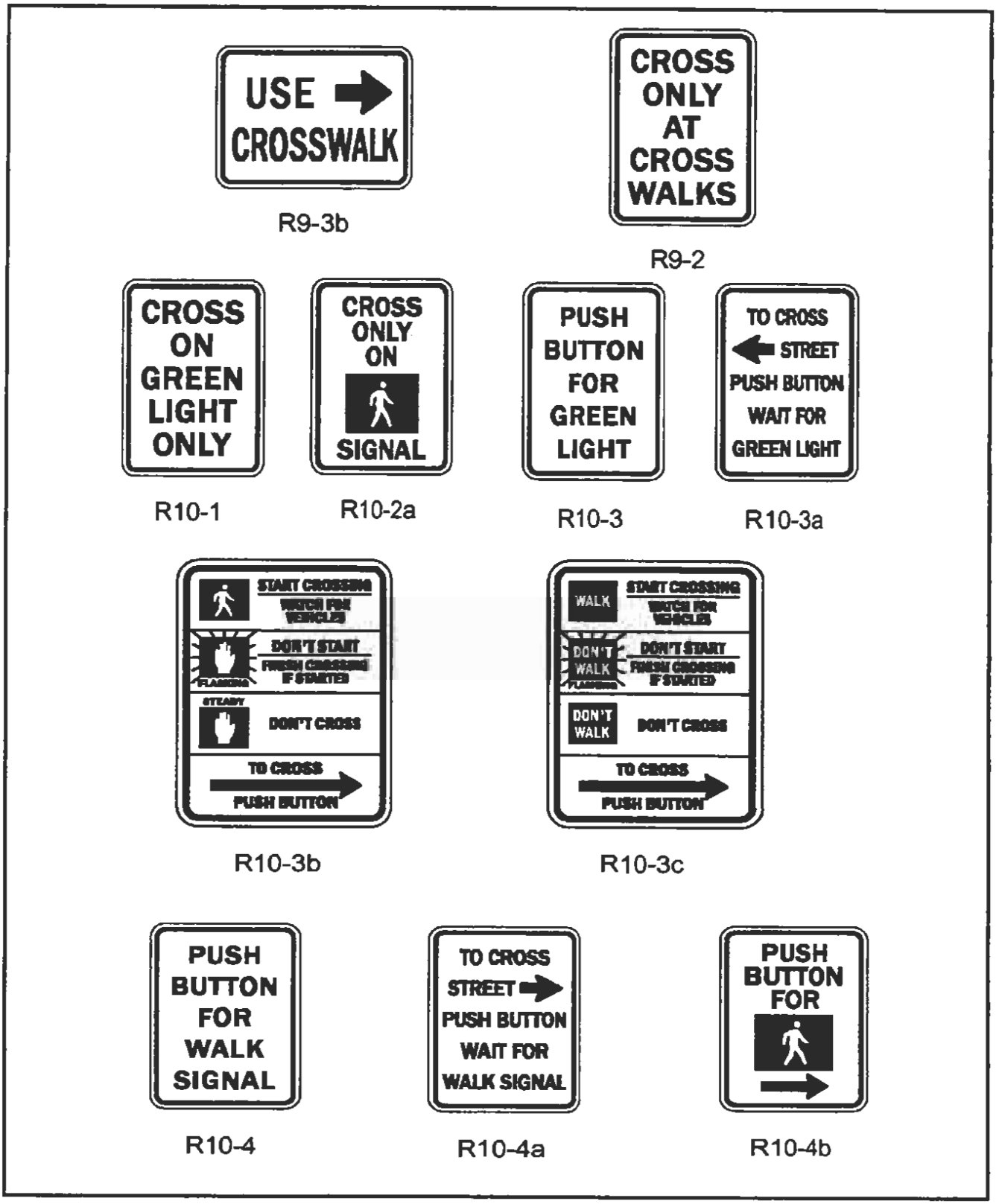
Length of Crosswalk

All crossings should be as short as possible to minimize pedestrian exposure. The uses of bulbouts or refuge islands (see below) are accepted methods that can decrease the exposure length. Bulbouts are curb extensions at the locations of pedestrian crossings with the purpose of decreasing the pedestrian's exposed crossing distance. A refuge island is a raised median used as a resting platform for crossing pedestrians at lengthy crossings. The Portland Pedestrian Design Guide recommends that 15m (50ft) be the maximum length of uninterrupted unsignalized crossings.

The 1995 *Pedestrian Area Policies and Design Guidelines* from the Maricopa Association of Governments states that curb extensions or medians used for refuge should be created when streets are wider than two lanes. (*59*)

Pedestrian Crossing Warning and Regulatory Signs

Figure 3-4 displays typical crossing regulation signs included in the MUTCD.



SOURCE: *MUTCD*

Figure 3-4: Regulatory Signs Pertaining to Crossing Pedestrians

Australia uses a set of walking legs as a symbol for pedestrian crossing. They also use a sign with a child symbol and vehicle symbol side by side with the message, "SHARED USE". (*90*)

Lighting

Street lighting should be used when the minimum mutual sight distances in AASHTO green book are not met. (*38*) Warrants for lighting depend on road classification, pedestrian and vehicle volumes, night to day ratio of collisions, and the roadway geometrics. (*43*)

Bulbouts

Bulbouts are curb extensions at the location of pedestrian crossings. The intended purpose of a bulbout is to increase pedestrian safety by reducing the crossing pedestrian's exposed travel distance, making a waiting pedestrian more visible to the motorists, and possibly slowing traffic due to the more narrow roadway section.

Refuge Islands

In general, pedestrians should not have to wait more than 60 seconds for a safe break in traffic to cross. When safe gaps do not occur frequently, pedestrians will be tempted to proceed during an inadequate gap. The addition of refuge islands or adjusting the phase timing nearby traffic signals may increase the number of suitable gaps. A refuge island is a raised median used as a resting platform at lengthy crossings.

Refuge islands make the task of crossing a roadway simpler. Refuge islands provide space for pedestrians to rest or wait when crossing a roadway. Pedestrians must only consider one direction of traffic at a time and the distance at each interval is greatly reduced.

Refuge islands can be particularly advantageous at intersections in urban areas where significant pedestrian traffic and heavy vehicular traffic exist making pedestrian crossing movement difficult and dangerous. Three specific conditions that may be well served by refuge islands are multilane roadways, large and irregular shaped intersections, and signalized intersections with multiple traffic streams. (*45*)

The North Carolina DOT recommends the following situations as locations that refuge island can be advantageous (*50*):

- Wide, two-way streets (at least four lanes) with high traffic volumes and speeds, and large pedestrian volumes;
- Wide streets which elderly, disabled, and children often cross.
- Streets in which the "walk" time is insufficient for pedestrians to cross the entire width.
- Wide, two-way intersections with significant pedestrian traffic and high traffic volumes.
- Low volume side street traffic demands when the traffic signal green time is insufficient for pedestrians to cross and the traffic signal has no pedestrian timing.

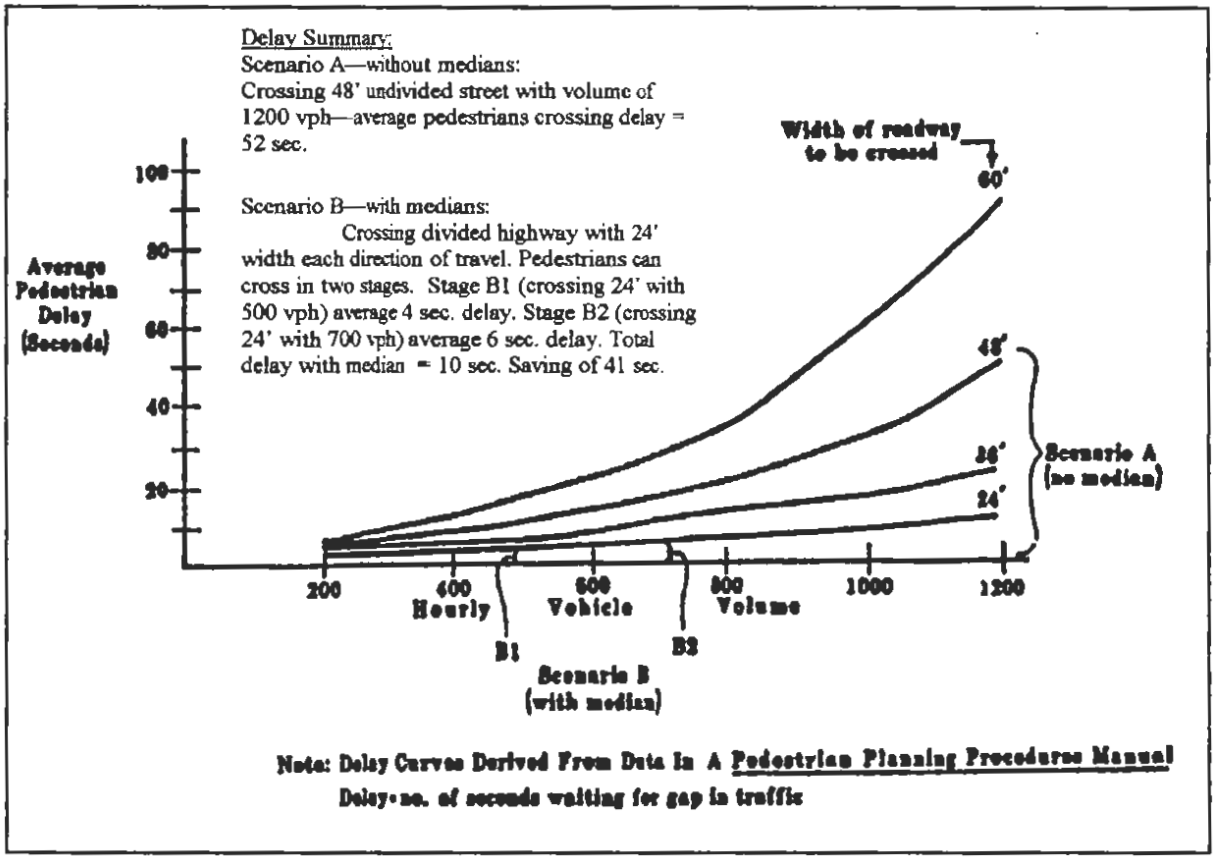
Refuge islands should preferably be at least 1.8 m (6ft) in width and may at no time be less than 1.2m (4ft). The useful length should not be less than 3.6m (12ft) or

the width of the crosswalk whichever is greater. (*45*) Barrier curbs equipped with a barrier marker for visibility should be used on refuge islands in areas of high traffic. (*38*)

The following design guidelines for medians and refuge islands appear in the 1998 *Pedestrian Facilities Guidebook (WSDOT)*. (*31*)

- Medians and refuge islands should be a desirable width of 2.4 to 3 meters (8 to 10 feet) wide and a minimum width of 1.8 meters (6 feet) wide to prevent wheelchairs propelled by attendants, bicyclists, and people with strollers from projecting out into the stream of motor vehicle traffic. In some cases, smaller width medians and refuge islands may be acceptable, particularly when there is limited space in the right-of-way, depending on local requirements and existing conditions.
- In order to obtain appropriate median width, travel lanes can be narrowed to 3.3 meters (11 feet), if allowed by local standards. In locations where vehicle speeds range from 32 to 48 kph (20 to 30 mph), the travel lanes can be reduced further to 3.0 to 2.7 meters (10 or 9 feet), if allowed by local standards.
- Trees in medians and at the sides of streets can help to narrow the long range field of vision for approaching drivers, causing them to slow down as they near the crossing point. Landscaping in median refuge islands must be handled carefully. It is essential that landscaping not block the sight lines of pedestrians and motorists at the crossing area.
- Curb ramps or full cut-throughs should be installed in all median refuge islands. Cut-throughs are more common because the median width is sometimes not large enough to accommodate ramps that meet the ADA requirements. Cut-throughs should be designed with a 2 percent cross slope to allow water, silt, and debris to drain from the area.
- A pedestrian push button should be placed in the median of signalized mid-block crossings where the crossing distance exceeds 18.2 meters (60 feet).
- The use of angled (45 degrees+) refuge areas in the island should be considered (see figures later in this section). These provide the benefit of directing and encouraging pedestrians to look in the direction of oncoming traffic, helping them to be more aware of approaching vehicles. Pedestrians are also prevented from darting directly out into traffic.
- Medians and refuge islands should be illuminated.

Figure 3-5, on the following page, illustrates the reduction in pedestrian delay introduced by a median or refuge island.



SOURCE: NCHRP Report 294A—*Planning and Implementing Pedestrian Facilities in Suburban and Developing Rural Areas.* Smith, Opiela, Impett, Pietrucha, Knoblauch
Figure 3-5: Saving of Pedestrian Delay by Installation of Median or Refuge Island

Passive Detection

Passive detection will identify a pedestrian at a crossing area with no action. An advantage is that the call can be canceled if the pedestrian crosses in a gap before the signal change, thus reducing unnecessary traffic delays. Passive detection may also be employed to identify slower users still in the crosswalk at the scheduled time of signal change and lengthen the interval when necessary.

In-Pavement Flashing Amber Warning Lights

An Intelligent Transportation System (ITS) used for pedestrian crossings is the flashing in-pavement crosswalk lighting. It is designed for use at unsignalized mid-block pedestrian crossing locations. The system has been found to increase the percentage of drivers who yield to pedestrians and also pedestrian/vehicle conflicts have been found to be less likely to occur at these locations. Both pedestrian push button activation and automated detection have been used. (*60*)

In 1998 Westernite reported that the experimental device has a base diameter of 19cm (6.75in) and a total height above pavement after installation of 3.2cm (1.25in). The system was further described as each unit including, "a 3-inch by 1-inch (7.6cm by 2.5cm) light enhancing optical lens in front of 12 amber LEDs." The

overall cost is comparable to a flashing beacon mounted on an overhead mastarm pole. (*61*)

Howard County, Maryland reported the implementation of similar in-pavement warning devices. The specifications for the model used were a 1.3 cm (0.5in) height above pavement and each fixture is 20.3cm (8in) in diameter. This low height enables snowplow blades to safely to pass over the fixtures. 45-Watt lamps are used with yellow lenses. (*62*)

Whitlock & Weinberger Transportation Inc. found that flashing amber lights embedded in the pavement have a positive effect in uncontrolled crosswalks. The effects were more pronounced during poor visibility conditions including darkness, rain, and fog. While the study showed that the initial positive effects will be somewhat reduced in the long term for daylight conditions, the driver's reaction characteristics will be improved from prior to installation. (*63*)

The system has been found to be especially effective for locations with a flow greater than 100 crossing pedestrians per day. It is stated that automatic detection is less confusing and more convenient for the pedestrian than the push button type activation system. Motorists at 56kmph (35mph) tended to respond appropriately when at least 122m (400ft) of sight distance existed and at a speed of 64kmph (40mph) tended to have difficulty stopping when less than 183m (600ft) of sight distance existed. One concern for safety is that the system may cause problems for bicyclists when lights are present at the edge of the roadway. (*63*)

A study in Kirkland, Washington found that the application of the in-pavement lighted crosswalks caused an increase in the number of vehicles yielding to pedestrians and an increase in the distance in which drivers apply their brakes to yield at the crosswalk. (*64*)

Other Crosswalk Safety Features

Illuminated Overhead Signs

A study of several unsignalized intersections in Clearwater, Florida have found that internally-illuminated overhead crosswalk signs accompanied by high visibility crosswalks increase the percentage of drivers yielding to pedestrian by 30-40% during the day and by 8% during the night. A high visibility crosswalk is a specially marked crosswalk with the intent to draw added motorist attention. Examples include the zebra, piano, ladder, and solid styles shown in Figure 3-3b,c,d&f. The number of pedestrians who looked before entering the crosswalk, forced the right-of-way, and ran across the road was not affected. In addition the incidence of pedestrian/vehicle conflicts remained unchanged. (*60*)

Toronto, Ontario has hundreds of internally illuminated overhead crossings signs with push button activated flashing beacons. Studies have found a decrease in pedestrian fatalities with this treatment. (*60*) When these beacons are accompanied by a pedestrian (symbol) crossing sign and a message, "STOP WHEN FLASHING" the number of motorists yielding increases.

The 1999 *Canadian Research on Pedestrian Safety* suggests that the use of Light Emitting Diode (LED) animated scanning eyes may be more effective than the flashing beacon as a pedestrian warning device. These are lighted eyes displayed on a black background appearing to scan side to side. It is intended that when drivers see

the scanning eyes they will be alerted to scan and look for pedestrians. It is speculated that the scanning eyes would be as conspicuous as a flashing beacon but would naturally prompt drivers to search for pedestrians. (*57*)

The city of Tucson, Arizona has implemented an overhanging regulatory fiber optic sign stating, "STOP FOR PEDESTRIANS IN CROSSWALK" that is activated immediately by a pedestrian push button. The flashing phase was typically set to accommodate a walking speed of 1.2m/s (4ft/s) plus 5 seconds. They have been installed on multilane highways with speeds not greater than 64kmph (40mph), where vehicles tend not to yield to the pedestrian traffic. A study by Huang and Zeeger found that this did not increase the numbers of motorists who yield to pedestrians. City traffic engineers were prompted to work with local police for enforcement. Huang and Zeeger suggest that this type of regulatory signs may be more effective on two lane roads with speed limits between 48 and 56kph (30 and 35mph).

Intelligent Crossings

Pedestrian User Friendly Intelligent crossings recognize, by infrared or microwave sensors, when pedestrians are lingering in the crosswalk. While sensors detect pedestrians in the crosswalk, the traffic signal is prohibited from changing to a green phase for conflicting traffic. These have been used for pedestrian crossings that typically accommodate slower pedestrian traffic such as in proximity to hospitals, retirement homes, and schools. (*57,65*)

The 2000 MUTCD advises the optional use of passive pedestrian detection equipment to avoid using a lower walking speed to determine the pedestrian clearance time.

Warning Signs Within Crosswalks

Warning Signs within Crosswalks—New York State Department of Transportation has developed specifications for a new Supplementary Pedestrian Crossing Channelization Device that could be placed within crosswalks. The device is constructed of the traffic cone rubber and is fitted with a safety orange retro-reflective fabric jacket displaying the state law message, "YIELD TO (PEDESTRIAN WALKING MAN SYMBOL) IN YOUR HALF OF ROAD" shown in Figure 3-6. It is only intended for use at unsignalized, marked crosswalks where the speed limit is not greater than 48kmph (30mph). It should be used in addition to any other necessary pedestrian warnings and pavement markings. The cost of each device is $125. (*66*) WSDOT documents that a similar device is being used in New Jersey that reads "STOP FOR PEDESTRIAN IN CROSSWALK." New Jersey had a previous hard material version that was banned due to the concern of creating harmful projectiles if hit by a vehicle. These devices have been found to increase pedestrian safety, but concerns of vandalism and deliberate damage have become a problem. (*60*)

Raised Crosswalks

A raised crosswalk is a combination of a speed hump and crosswalk. The cross-section of a raised crosswalk is similar to a speed hump with the exception of a flat surface at the top portion of the hump. The pedestrian is provided a level walking surface for crossing the roadway.

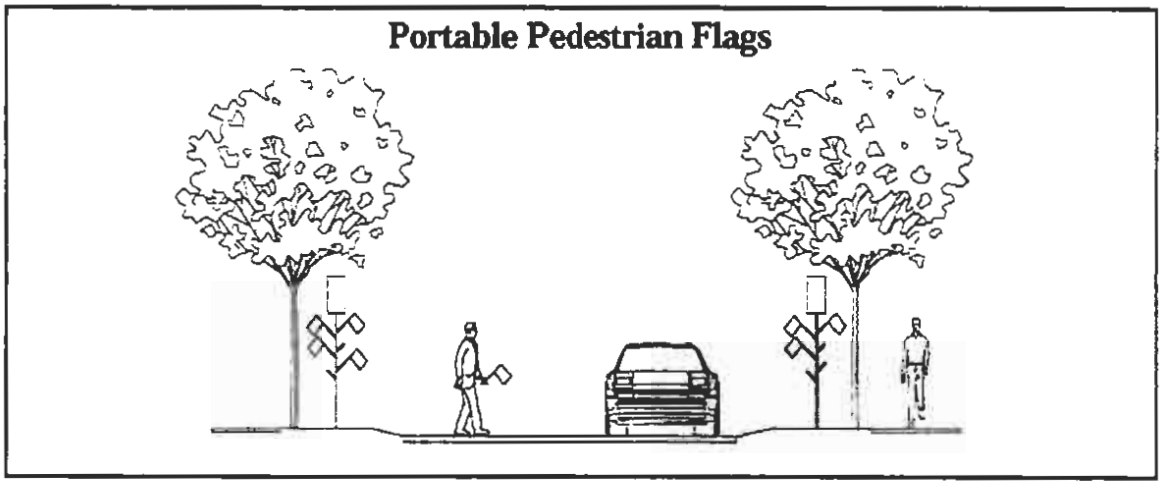
SOURCE: *Everyone is a Pedestrian, New York State Pedestrian Safety Engineering Toolbox*
Figure 3-6: Supplementary Pedestrian Crossing Channelization Device Message

The flat section often has a brick or other type of textured surface. Markings and signs distinguish the raised section as a pedestrian crosswalk. Raised crossings are being used in Sparks, Nevada; Beaverton and Eugene, Oregon; Tallahassee, Florida; and Montgomery County, Maryland.

Pedestrian Flags

The cities of Kirkland, Washington; Berkeley, California; and Salt Lake City, Utah have implemented a portable pedestrian flag program. (*31,93*) Bright orange flags similar to those used by road crews are available at selected uncontrolled crossing locations. The flags are to be picked-up by the pedestrian before crossing with the intent of making the crossing pedestrian more visible. The flag is then left at the exiting side of the crossing. The expected cost is $250 per location. (*93*)

The *Pedestrian Facilities Guidebook* states that the implementation of the portable pedestrian flags, "have been viewed as an effective measure to increase driver awareness of upcoming crossing activity." Observations have shown that not all pedestrians use the portable pedestrian flags when available. There is some concern for the probable theft of the flags. The flags cost $1 a piece and in Berkley it has been decided that they will continue to replace flags until everyone who wants one has stolen one. (*93*) Figure 3-7 is an illustration of the portable pedestrian flag program.



SOURCE: *Pedestrian Facilities Guidebook. WSDOT*
Figure 3-7: Portable Pedestrian Flags

Railroad Crossings

Trains possess the right of way at railroad crossings. To increase pedestrian safety at railroad crossing locations two options are possible. The first is to stop pedestrians from entering the track area while trains are approaching or present and the second is to provide a grade separated crossing facility.

Grade separated crossing structures are expensive and are appropriate only under heavy pedestrian traffic conditions. Railroad crossings that are located on school routes may be candidates for a grade separated pedestrian crossing. A crossing guard should be considered as a lower cost alternative in school routes. A warrant analysis should be conducted. (*31*)

When pedestrians cross railroad tracks, the surface should be smooth. Timber, asphalt, rubberized material, and concrete surfaces are used at crossings. Concrete is recommended due to the smoothness created and durability of the material. Timber tends to wear down and is slippery when wet. Maintenance must be periodically performed for asphalt to prevent bulging next to the rails. Rubberized surfaces can create a smooth path but becomes slippery when wet. (*31*)

The ADA requires a maximum elevation difference at pavement joints or between adjacent surfaces of 1.3 cm (0.5 in). Pedestrian crossings should form an approximate right angle with the railroad tracks. Signs and pavement markings should be located to warn pedestrians, bicyclists, and vehicle operators of upcoming railroad crossings. (*31*)

Maintenance

Plastic crosswalk markings are more desirable than paint because of longer life and a shorter drying time reducing the need for extensive barricades. (*32*)

Marked crosswalks should be maintained and removed if determined to be no longer appropriate for the location. (*32*) Properly removing pavement markings is not a simple nor inexpensive procedure. Removal must be done properly so the markings will not reappear. Ghost markings that remain after removal, especially with wet

pavement conditions, are also a concern. Pavement resurfacing may be necessary to completely remove markings.

Pedestrian Warrants for Signalization

The ITE *Design and Safety of Pedestrian Facilities* states that the purpose of traffic signals is to assign right-of-way for both pedestrian and vehicular traffic. To reduce hazards, pedestrian signal faces are recommended when the signalization is complex.

Washington Department of Transportation's 1997 *Pedestrian Facility Guidebook* states that where adequate crossing gaps do not occur, considered to be on average less than one a minute, traffic control is required for crossing pedestrians. A pedestrian actuated signal may be appropriate when high traffic volumes or speeds exist. (*31*)

The 1998 Portland Pedestrian Design Guide states a traffic light may be warranted where the pedestrian volume crossing a major street at either an intersection or mid-block location for an average day exceeds 100 per hour for any four hours or 190 for any one hour. These warrants may be reduced up to one-half where the primary pedestrian crossing speed is less than 1m/s (3.5ft/s).

In conjunction with the minimum pedestrian volume there must be less than 60 adequate crossing gaps per hour. In a location where a median exists, each side of the road will be measured independently.

An existing traffic signal cannot be located within 91m (300ft) of the site under study for possible traffic signal installation. Also a signal may not be placed where it would restrict platooned flow of traffic.

If a signal is added under the guidelines of these warrants, a traffic-actuated type should be used with pedestrian push-buttons and pedestrian indications. (*39*)

Warrants for Pedestrian Signal Indications

The 1998 Portland Pedestrian Design Guide also suggests pedestrian signal indications may be installed with vehicular traffic signals if at least one of the following is met:

- Traffic signals installed under the Pedestrian Volume or School Crossing warrant
- Exclusive pedestrian movement is allowed with all conflicting vehicle movement stopped
- Vehicular indications are not clearly visible to the pedestrians
- Signalized school crossing established under any warrant
- Pedestrian clearance interval is necessary to aid pedestrians for safe crossing
- Multi-phase indication may confuse pedestrian being led by vehicle signal
- Placement of refuge island only allows for one direction of traffic to be crossed during one interval

For Design Requirements and Location see MUTCD section 4D-4 & 4D-5.

Provisions at Signalized Intersections (Without Pedestrian Signal Faces)

Decisions to use a particular traffic control treatment should be based on an engineering study of that location. The MUTCD gives standards for installation of traffic control devices but not legal requirements.

The MUTCD states in locations of signalized intersections without pedestrian signal faces, pedestrians must be able to:

1. see the traffic signal indications
2. have opportunity to cross without excessive delays (pedestrian actuated button may need to be installed)
3. have sufficient time to cross (pedestrian actuated button may need to be installed)

Pedestrian detectors are usually of the push button type. They should be located 1.1-1.2m (3.5-4ft) above the pavement and near the end of a crosswalk where actuation is required. A sign 2B-37 shall be mounted above or in the unit explaining its use and purpose. In locations where two crosswalks are at the same corner, signs should clearly indicate which button corresponds to the appropriate signal.

Timing of Pedestrian Signal Indications

Complaints that the timing intervals for pedestrian crossings are not sufficient are common. One survey found that this was the top complaint of older pedestrians. (*30*) Some pedestrians are confused by the meaning of pedestrian signals.

Portland, Oregon has new signs explaining the significance of the steady hand, flashing hand and steady walking man symbols. Pedestrians should only enter a crosswalk during the "WALK" or steady walking man phase. The flashing hand will most likely appear during the time the pedestrian is still crossing the street. During the flashing "DON'T WALK" or hand, the pedestrian should continue across the street but not enter from the curb. Pedestrians should no longer be in the crosswalk during the steady "DON'T WALK" or hand interval. (*39*)

The "WALK" interval should be a minimum of 4 to 7 seconds in length. The clearance interval (flashing "DON'T WALK) should be timed so that the total width of the roadway from one curb ramp to the other can be traveled. The appropriate walking speeds to use in the calculation should be 1.2m/s (4ft/s) or 1.1m/s (3.5ft/s) can be used to better accommodate the disabled. (*45*)

Alternate sources such as *The Portland Pedestrian Design Guide* state that 3.5 ft/s is more appropriate to accommodate older pedestrians. The 2000 *MUTCD* states, "Where pedestrians who walk slower than normal, or pedestrians who use wheelchairs, routinely use the crosswalk, a walking speed of less than 1.2 m (4 ft) per second should be considered in determining the pedestrian clearance time."

A study of walking speeds in crosswalks by Knoblauch, Pietrucha, and Nitzburg found that the 15th percentile of older pedestrians (specified as 65 and older) was 0.97 m/s (3.19 ft/s). The conclusion to this study was that a design speed of 0.9 m/s (3.0 ft/s) was appropriate for older pedestrians. (*67*)

The *Capacity Analysis of Pedestrian and Bicycle Facilities: Recommended Procedures for the "Pedestrians" Chapter of the Highway Capacity Manual*

recommends the usage of a pedestrian crossing speed of 1.2m/s (3.9ft/s) for most situations but in locations with a "large number of older pedestrians" a rate of 1.0m/s is recommended. The document distinguishes the "large number of older pedestrians" to be the number which results in an alteration of the overall speed distribution of the facility. Specifically the study states that when older pedestrians make up more than 20% of the facility users, the 1.0m/s rate should be used. It is also recommended that the minimum crossing time be extended at signalized crossings where a typical crossing platoon exceeds 15 pedestrians. Flow may also be impeded where a stop bar does not exist, high visibility crosswalks do not exist, and the sidewalk is not aligned with the natural pedestrian flow. (*27*)

The 1999 *Designing Sidewalks and Trials for Access—Review of Existing Guidelines and Practices* states that the use of a 0.85m/s (2.8ft/s) walking rate may be more appropriate for the accommodation of older pedestrians. (*30*) It is important to note that walking rates depend on many factors. Rates are faster at mid-block crossings and for men opposed to women. Rates also vary depending on purpose of trip, climatic conditions, steepness of grades, and time of day. (*52*)

Capacity Analysis of Pedestrian and Bicycle Facilities: Recommended Procedures for the "Pedestrians" Chapter of the Highway Capacity Manual recommends that a pedestrian start-up time of 3 seconds be used. The 50th percentile was found to be 2.5 seconds while the 85th percentile was found to be 3.75 seconds. (*27*)

Generally the "WALK" interval should be as long as possible after considering the green signal phase for traffic. The "WALK" timing can be calculated by subtracting the necessary clearance interval from the overall green signal phase. In places where the pedestrian clearance timing and "WALK" phase together will be longer than the green traffic signal phase, the minimum "WALK" timing should be used. (*39,45*)

The City of San Francisco Parking and Traffic provides a crossing interval that will accommodate pedestrian traffic walking at the rate of 2.5ft/s. Where this timing will significantly affect traffic congestion pedestrians walking at the rate of 2.5ft/s are provided enough time to cross to the median and must compete the crossing during the next phase. (*68*)

A study by the Insurance Institute for Highway Safety found that releasing pedestrians 3 seconds before turning vehicles reduced the number of conflicts and the incidents of pedestrians yielding the right of way to vehicles. The study defined a conflict to be a situation in which a vehicle abruptly braked or the pedestrian or motorist took "sudden evasive action to avoid a collision."

The 3-second leading interval reduced the odds of a pedestrian being involved in the defined conflict by approximately 95%. The odds of a pedestrian yielding to a turning vehicle were reduced by 60%. (*70*)

Pedestrian Detection

Mid-block crossings with signals are always pedestrian activated. Signalized crossings at intersections can be either pedestrian activated or pre-timed.

The most common pedestrian detection device is of the push button type. In some situations the "WALK" phase follows in a few seconds but in many locations the

"WALK" interval will accompany the appropriate green traffic signal phase and the delay can be a minute or more. Pedestrians can become discouraged with the belief that the call button is inoperative and cross against the signal. The *Portland Pedestrian Design Guide* states that a push button that lights upon activation (such as an elevator button) may be helpful in this situation but some technical difficulties have been experienced. (*39*)

The life of the push button actuator may also be increased. This extended life would be due to approaching pedestrians who will observe that a call has been received, resulting in fewer depressions per cycle.

Another alternative to convey to the pedestrian that they have been detected is an LED countdown displaying the time remaining until the next walk indication. It is thought that this type of countdown timer would encourage pedestrians to wait for their crossing phase because a definite amount of waiting time has been established to the pedestrian.

Passive detection will identify a pedestrian at a crossing area with no action. An advantage is that the call can be canceled if the pedestrian crosses in a gap before the signal change, thus reducing unnecessary traffic delays. Passive detection may also be employed to identify slower users still in the crosswalk at the scheduled time of signal change and lengthen the interval when necessary.

Encouragement to Search for Turning Vehicles at Signalized Intersections

The Insurance Institute for Highway Safety has conducted studies concerning pedestrians searching for turning vehicles during the walk interval. Two treatments were examined and a third is planned for study.

In a Canadian study, the words, " WATCH FOR TURNING VEHICLES" were posted on a sign and/or painted within the crosswalk. It was observed that before the treatment, 15-18% of pedestrians did not look for turning vehicles at any time during crossing. After the implementation of sign or pavement markings, the percentage of pedestrians that did not look for turning vehicles was reduced to 5-10%. When both measures were used concurrently, the percentage was reduced to 3-8%.

An auditory message stating, "Please wait for WALK signal," is played when the pedestrian push-button is depressed. A second message stating, "Look for turning vehicles when crossing [street name]," is played 0.2 seconds before the pedestrian signal head displays the walk symbol. Before this messages were added, only 18% of pedestrians were observed to look for turning vehicles. When a woman's voice spoke the messages, 40% of pedestrians were observed to search for turning vehicles. A child-like voice was also studied and it was observed that well over 40% searched for turning vehicles.

An experiment is planned in Florida adding a set of lighted eyes to pedestrian signal heads. The pupils of the eyes will accompany the steady walk symbol appearing to scan back and forth 2 times per second for the first two seconds of the walk phase. The remaining steady walk symbol will not include the scanning eyes.

Pedestrian Scramble

The City of San Francisco Department of Parking and Traffic reports the use of the pedestrian scramble crossing phase. All vehicular traffic is stopped in all

directions and pedestrians may cross in any direction including diagonally. It has been found to be most effective in areas of very high pedestrian traffic volumes. (*68*)

Roundabouts

Modern roundabouts were established in the United Kingdom in the 1960's to address traffic congestion within traffic circles. Traffic circles are a circular intersection giving priority to entering vehicles. After experiencing difficulties due to congestion at traffic circle locations the United Kingdom mandated a rule altering the priority from entering vehicles to vehicles within the circular intersection. An additional change was that the radii of the circular intersections began to be reduced promoting drivers to travel at slower speeds. These two significant changes introduced the modern roundabout.

An ITE technical committee conducted an international survey for traffic control agencies on experience with roundabouts. The comments for the benefits of roundabouts included:

- Contributes to free flow traffic
- Applicable to residential areas
- Perceived as safer
- Reduction in delays
- Suitable for low to moderate traffic volumes

The negative comments included "high crash rates," "potentially confusing," "take much space," "high delays," and "limited capacity." However, none of these negative comments came from England where the roundabout is an established design. Therefore, it was concluded by the authors that these negative comments were not relevant to the current design standards. (*70*)

Definition and Components of Roundabouts

The 2000 *Roundabouts: An Informational Guide* defines a roundabout as, "a circular intersection with yield control of all entering traffic, channelized approaches, counter-clockwise circulation, and appropriate geometric curvature to ensure that travel speeds on the circulatory roadway are typically less than 50 km/h (30 mph)." (*71*)

Circular intersections must possess all of the following characteristics to be correctly labeled as a roundabout.

- Yield Control Upon Entry—Yield control for all entries and no control for circular through traffic.
- Circulating Vehicles Assigned Priority—Right-of-way is established for circulating vehicles.
- Pedestrian Accommodation—Pedestrian crossings are only provided at the leg locations and prior to the yield controls.
- Restricted Parking—No parking is allowed within the roundabout.
- Counterclockwise Travel—All vehicles must circulate in the counterclockwise direction.

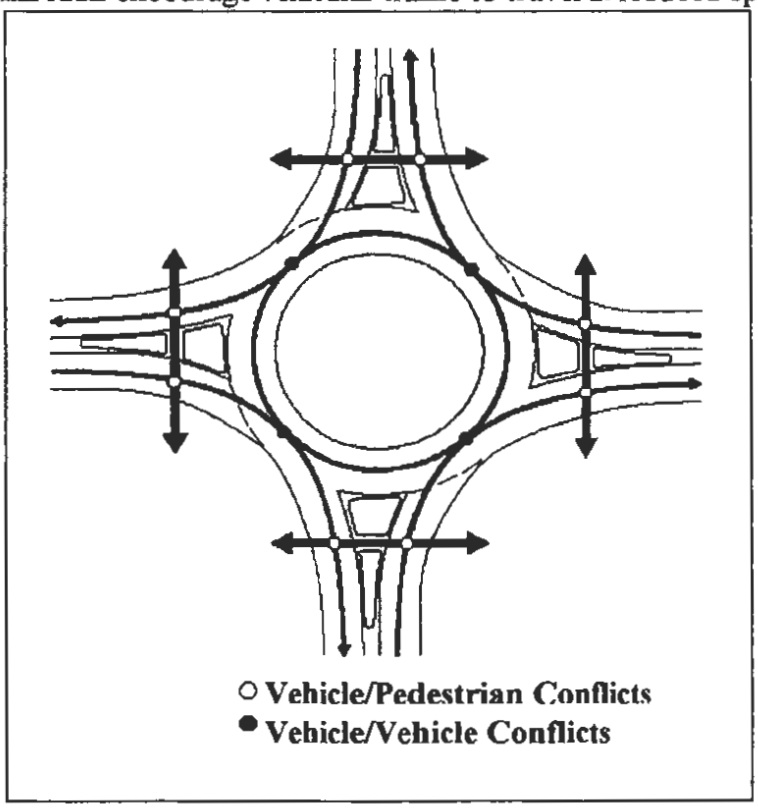
Additionally roundabouts may have the following characteristics to produce the desired effects for a specific location:

- Speed Reduction—An entry with a small radius will encourage reduced speeds.
- Design Vehicle—Large vehicles will require additional consideration at small roundabouts.
- Entry Flare—A flared entry widens the approach into multiple lanes prior to the yield control for the purpose of added storage capacity.
- Splitter Islands—Provides raised curb separation of entering and exiting vehicles and also provides refuge island for pedestrian crossings.
- Pedestrian Crossing Locations—Pedestrian crossing are located at least one vehicle length prior to the yield point.

Pedestrian-Vehicle Conflicts at Roundabouts

In the 2000 *Roundabouts: An Informational Guide*, the number of vehicle/pedestrian conflicts at a roundabout is compared to the number of vehicle/pedestrian conflicts at a signalized intersection. Including both legal and illegal movements by vehicles, there are 16 conflicts at a standard right-angle intersection. In contrast, at the roundabout intersection two vehicle/pedestrian conflicts exist at each approach leg, specifically vehicles entering the roundabout and vehicles exiting the roundabout. Figure 3-8 diagrams the vehicle/pedestrian and vehicle/vehicle conflicts at a roundabout.

In addition to the purpose of simplifying movements at intersection locations, roundabouts have also been characterized as traffic calming devices. Narrow entries and relatively small radii encourage vehicular traffic to travel at reduced speeds.



SOURCE: *Roundabouts: An Informational Guide (2000)*

Figure 3-8: Vehicle/Pedestrian Conflicts at Roundabout

Pedestrian Safety at Roundabouts

Roundabouts, when compared with signalized intersections, reduce the potential for pedestrian to be involved in a serious collision due to two factors:

- Decreased vehicle speeds
- Fewer conflict points

British collision statistics have found that the collision rate for pedestrians is decreased at roundabouts. The collision data finds that at signalized intersections the number of pedestrian crashes per million trips is 0.67; while the rates range from 0.31-0.45 pedestrian crashes depending on the types of roundabouts.

A Dutch study found that after changing 181 intersections to roundabouts the number of total pedestrian collisions decreased by 73% and the number of pedestrian injury collisions decreased by 89%.

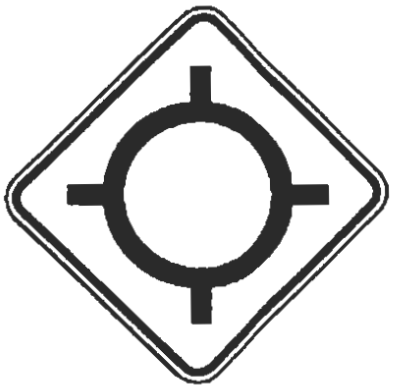
Crosswalk Markings at Roundabouts and Warning Sign

The 1998 *Modern Roundabouts for Oregon* states that an unmarked crosswalk at a roundabout cannot fulfill the vehicle code's legal definition of a crosswalk. (*72*)

It is stated in the 2000 *Roundabouts: An Informational Guide* that in the United States it is recommended to provide zebra striped crosswalk markings for roundabouts. However, the guide does not state where the recommendation originated.

No research data has been collected concerning the issue of the benefits of high visibility crosswalks at roundabouts. Due to lack of evidence supporting increased safety, most other countries to not practice zebra striping at roundabouts.

The 2000 *MUTCD* includes a warning sign for roundabout intersections, which is shown in Figure 3-9.



W2-6

SOURCE: *MUTCD*

Figure 3-9: Warning Sign for Roundabout Intersection

Pedestrian Crossing Locations at Roundabouts

The location of the pedestrian crosswalk should be a balance of accounting for pedestrian convenience, pedestrian safety, and the overall operation of the roundabout.

Pedestrians will tend to see direct paths as more desirable and may not cross at designated crossings if perceived as inconvenient. The pedestrian crossing should not be indiscriminately distanced from the direct path.

For increased pedestrian safety the crossing distance should be minimized to decrease vehicle exposure. It is appropriate to locate the pedestrian crossing to utilize the splitter island as a pedestrian refuge island. The yield control employed at the entrance of roundabouts can distract drivers from looking for pedestrians. Crosswalks should be placed at least a vehicle's length before the yield line.

Pedestrian crossings, if not adequately located, may hinder the flow of traffic within the circulatory roadway. Queuing analysis may reveal that a distance greater than one vehicle length is necessary for the placement of the pedestrian crossing to prevent congestion.

The 1998 *Modern Roundabouts for Oregon* references the French practice of locating crosswalks 4-5m (13-16.5ft) behind the vehicle's entry point. This will position the pedestrian crossing behind the waiting entering vehicle without unreasonably extending the travel distance of the pedestrian. A vehicle exiting the circular portion of the roundabout will have adequate space to clear the vehicle from the circulating traffic while waiting for a crossing pedestrian. A limitation to this placement of a crosswalk is that large trucks will cover the crosswalk when waiting to enter.

In areas with large volumes of pedestrian traffic, a French practice is to stagger the crosswalks at the entry and exit lane of the roundabout. Staggering the crosswalk allows greater room for waiting pedestrians on the splitter island. The crosswalk for the entry lane must be located farther from the roundabout so pedestrians are not forced to walk with their back turned to the traffic they will be crossing. (*72*)

At some locations in France, pedestrian are allowed access to the center island. Crossings must be controlled and located prior to the exit and never after an entrance location where drivers already have multiple tasks to complete.

Roundabouts and Visually Impaired Pedestrians

A roundabout presents unique challenges for the visually impaired pedestrian and considerations must be made to accommodate this group. The crossing action at roundabouts is complex for the visually impaired. First the crosswalk must be identified. This task may be difficult if not appropriately landscaped. A further challenge to the design is that the alignment of the crosswalk must be evident to the visually impaired.

The visually impaired pedestrian must listen for a gap in traffic to cross. Sound cues aiding in the action of crossing conventional intersections may be disguised by the circulating traffic. The splitter island must be identified as a refuge island. The task of listening for a traffic gap and deciding to cross must be repeated for the remaining half of the leg. The exit of a roundabout supports higher speeds than the entrance and is more hazardous to the pedestrian.

Unless these concerns are addressed, the crossing may be inaccessible and impermissible by the ADA.

Audible pedestrian signals may be considered at an approach to a roundabout to aid in the crossing of a visually impaired pedestrian. This is not a typical application. No specific standards have been adopted and individual professional judgment must be applied.

Remedies to Increase Pedestrian Safety at Roundabouts

Suggestions from the 2000 *Roundabouts: An Informational Guide* to create a safer pedestrian environment at roundabouts include:

- Tighten width of entry lanes.
- Provide raised speed tables with detectable warning.
- Increase ability for visually impaired pedestrians to identify crosswalks.
- Apply pedestrian signalization to crossings with actuation an adequate distance away to prevent traffic congestion in circular region.
- Raise pavement markers with flashing yellow warning lights at crosswalk.

These treatments have not been studied in the United States.

The 1998 *Modern Roundabouts for Oregon* documents French design considerations for pedestrians at roundabouts. It is stated that the main function of the splitter island is to allow pedestrians to cross a leg of the roundabout in two sections. The splitter island should have a cut through at the pedestrian crossing location and should provide a minimum 2m (6.6ft) waiting area. When the space does not allow for this width, a raised island as narrow as 0.8m (2.5ft) is preferable to a painted line.

Prediction of Pedestrian Injury Collisions at Roundabouts

Currently no collision prediction models for roundabouts exist for the United States. The following model was developed in the United Kingdom for the application on four-legged roundabouts. The development was based on a generalized linear regression of the exponential form assuming a Poisson's distribution. No added variable improved the model significantly.

$$A = 0.029(Q_{ep})^{0.5}$$

Where:
A = personal injury crashes (including fatalities) per year at roundabout approach or leg
Q_{ep} = product $(Q_e + Q_{ex}) \times Q_p$
Q_e = entering flow (1,000s of vehicles/day)
Q_{ex} = exiting flow (1,000s of vehicles/day)
Q_p = pedestrian crossing flow (1,000s of pedestrians/day)

The model simply states that higher vehicle and pedestrian volumes are related to a higher number of collisions. The model does not offer any help in designing safer roundabouts. (100)

TRAFFIC CALMING

Traffic calming has acquired varying definitions. Some agencies include engineering, enforcement, and education. Others assert that traffic calming is strictly an engineering application, but there is still further disagreement if engineering treatments should include speed reduction only or also route adjustments. This section will concentrate on the engineering aspects of both volume and speed control including the use of route modifications.

The ITE subcommittee on traffic calming defined traffic calming as:

...the combination of mainly physical measures that reduce the negative effects of motor vehicle use, alter driver behavior and improve conditions for non-motorized street users.

This subcommittee also restricted traffic calming to exclude the treatments of route modifications, streetscaping, and traffic control devices. The committee contended that route modifications such as diagonal diverters, forced turns, full closures, and half closures do not reduce the speed of traffic but only the options of paths. Street furniture, lighting, trees, and other streetscape elements do not directly cause drivers to slow. The committee members consider traffic calming as a means to slow traffic through the laws of physics and streetscape elements, and is also effective because of human psychology. Finally their view is that traffic control devices do not qualify as traffic calming because they must be regulated and traffic calming is intended to be self-enforcing.

The definition above is narrower than others. The 1999 *Traffic Calming: State of the Practice* clearly includes route modifications stating (*73*):

Traffic calming involves changes in street alignment, installation of barriers, and other physical measures to reduce traffic speeds and/or cut-through volumes, in the interest of street safety, livability, and other public purposes.

The Montgomery County, Maryland definition is the still more encompassing:

Traffic calming consists of operational measures such as enhanced police enforcement, speed displays, and a community speed watch program, as well as such physical measures as edgelines, chokers, chicanes, traffic circles, and (for the past four years) speed humps and raised crosswalks.

Roundabouts, as covered in the previous section, are included among the traffic calming techniques.

The Beginnings of Traffic Calming

In the Dutch city of Delft, during the late 1960's, a group of people became angered over traffic cutting through their residential streets. The residents began "sharing" the street by placing sandboxes, tables, benches, and parking bays in what was previously a vehicle only path. The idea was to create an obstacle course to slow the speeds of the motorists and discourage traffic short cutting through their neighborhoods while extending the area of their yards. (*74*)

The Dutch government gave official support to these "woonerven" or "living yards" in 1976. This idea spread during the next ten years and similar patterns were

used in Germany, Sweden, Denmark, England, France, Japan, Israel, Austria, and Switzerland.

The U.S. cities of Berkeley, California; Eugene, Oregon; and Seattle, Washington have also been involved with traffic calming treatments since the late 1960's and early 1970's. The first national study of traffic calming took place around 1980. The study examined preferences for traffic in residential areas, performance of speed humps, the adverse effects of high vehicle volumes and speeds on quality of life in residential areas, and legal issues concerning traffic calming. (*74*)

Purpose of Traffic Calming

Traffic Calming has become a feature for improving the quality of life on local streets—reducing air and noise pollution and creating safer streets for pedestrians, bicyclists, and children. Traffic calming, as opposed to regulatory measures, is intended to be self-enforcing.

Local residents see volumes over 2,000 vehicles per day as a problem. (*37*)

Pedestrians and bicyclists can benefit from traffic calming measures in the following ways (*36*):

- A reduction in traffic speeds and volumes enables non-motorized users to share the road.
- The combination of automobile noise reduction and a greater ease in crossing streets leads to a more pleasant pedestrian environment.
- The decrease in the speed of traffic increases safety.
- Parents will feel more comfortable allowing their children to walk or ride bicycles in a safer neighborhood.

One objective of traffic calming is to return the proper usage of the roads. Local streets should accommodate local traffic at slow speeds. Bicycles should be able to share the street and pedestrians should be able to cross easily. Streets classified as collectors should also have shared use with bicycles and pedestrians should have frequent opportunities to cross and buffered sidewalks. Arterial streets should accommodate mostly through traffic and allow bicycle travel in bike lanes. Pedestrians should have buffered sidewalks and be able to cross without unreasonable delays. (*36*)

Two Categories of Calming—1) Speed Control, 2) Volume Control

Engineering designs for traffic calming fall into two main classifications—speed control or volume control. The speed control calming consists of treatments that encourage slower speeds by reducing street widths or localized elevation changes of the pavement causing higher speeds to contribute to a rough, bumpy ride. Volume control calming is comprised of street closures and diversions.

However these categories are intertwined. Measures to reduce vehicle speeds tend to divert traffic to other routes and measures to reduce volumes tend to slow traffic.

Reducing Speeds

Reducing speed limits in the attempt to slow traffic has been found to be marginally effective. The average of the actual observed speed change has been found to be approximately one quarter of the speed limit reduction. (*70*)

Enforcement of speed limits is most likely to reduce vehicular speeds when one of the following circumstances exists. (*70*)

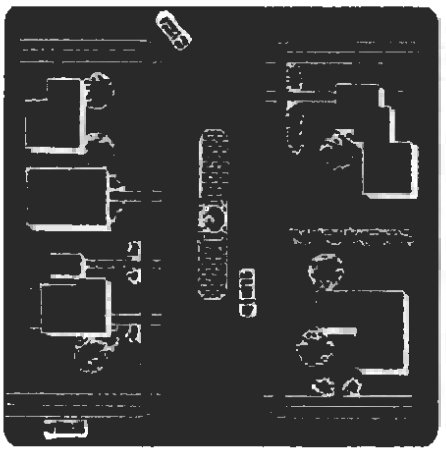
- Enforcement is believed likely to occur.
- Penalties are significant and costly to offenders.
- Enforcement is associated with driving in general, opposed to specific time or location.
- Enforcement is not associated with any signal alluding to presence or absence of enforcement officer.

A reduction in traffic speeds can be obtained by roadway design. Motorists drive at speeds in which they perceive as safe. Reducing the lane width or creating the illusion of a narrower roadway can help accomplish this goal. The following figures are examples of roadway treatments that will cause drivers to use slower speeds.

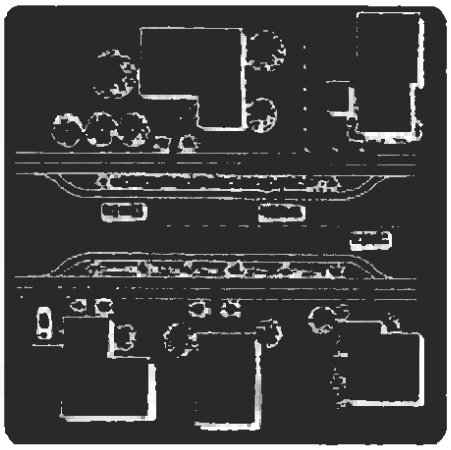
Figure 3-10a is a mid-block median also known as a center island narrowing, a median slow point, or a median choker, which narrows the available street width for driving. This treatment may also function as a pedestrian refugee island if a mid-block crossing is present or appropriate. The median can be landscaped for aesthetic purposes. A disadvantage is that it may only have a minor effect reducing speeds. (*37*)

Figure 3-10b, a choker, and Figure 3-10c, bulbouts, also serve the purpose of reducing the width of the street for the calming of traffic speeds. Chokers also known as two-lane slow points are curb extensions or islands at mid-block locations that can be applied to one or both sides of the roadway. Bulbouts also known as neckdowns, bulbs, nubs, and gateways are curb extensions at intersection locations. Curb extensions provide added area for pedestrians and landscaping. At crossing locations with curb extensions, pedestrians and motorists can also benefit from better views of one another. These treatments, along with the mid-block median, have an added advantage of reducing the exposed crossing distance for pedestrians.

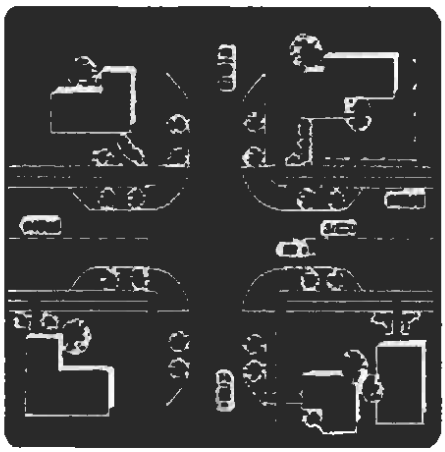
The National Center for Bicycling and Walking website states that bulbouts should only be installed on arterials where there is permanent parallel parking. The bulbout should extend a minimum of 2m (6ft) but preferably the full width of the parking bay, typically 2.5-3m (8-9ft). (*49*)



Mid-block Median (a)



Choker (b)



Bulbout (c)

SOURCE: www.trafficcalming.org

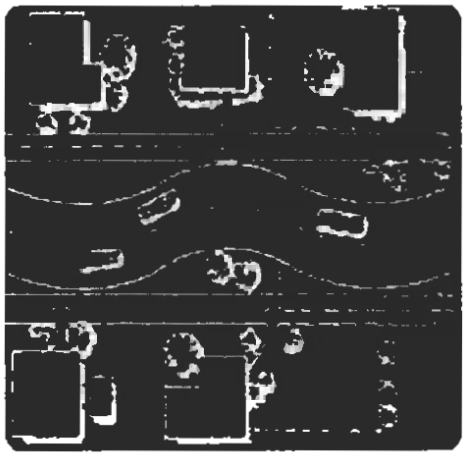
Figure 3-10a-c: Traffic Calming by Reduction of Roadway Width

Chicanes also known as deviations, serpentines, reversing curves, and twists (Figure 3-11a) are alternatively spaced curb extensions, islands, parking bays, or other barriers. They create a more complex and narrow street. The intention is that motorists will slow to negotiate the curvatures. Chicanes have been found to reduce collisions and speeds. Disadvantages are that on-street parking may be reduced, motorists attempting to pass bicycles on the narrow street may endanger the bicyclists, and some motorists may view the chicane as an obstacle course.

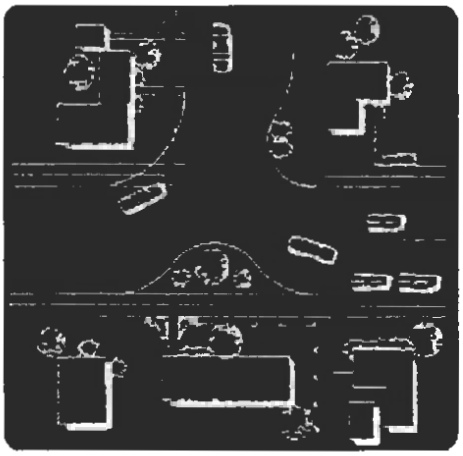
Realigned intersections also known as modified intersections (Figure 3-11b) are a curb extension, island, or other barrier at the "through" leg of a Tee intersection. Through traffic along the upper section of the Tee becomes a turning movement and priority may be shifted from the upper section to the base section of the Tee. This will reduce speeds and the volume of through traffic. This can be confusing and dangerous for users if inadequately designed.

The above methods that narrow the roadway may not adequately accommodate large vehicles. A remedy is to provide "overrun areas" which are widenings that are

slightly raised and surfaced with a tactile material such as cobblestone. Larger vehicles will have acceptable space for travel and cars will tend to slow for the perceived narrow road. (*70*)



Chicane (3-11a)



Realigned Intersection (3-11b)

SOURCE: www.trafficcalming.org

Figure 3-11a-b: Traffic Calming by Alternate Alignments

Speed humps also known as road humps, undulations, or "sleeping policemen" (Figure 3-12a); speed tables also known as trapezoidal humps, or speed platforms (Figure 3-12b); raised crosswalks also known as raised crossings, or sidewalk extensions (Figure 3-12c); raised intersections also known as raised junctions, intersection humps, or plateaus (Figure 3-12d); and textured pavements (Figure 3-12e) are also intended to reduce the speed of traffic. These treatments discourage speeding by making the ride less comfortable for vehicles traveling at higher rates.

Speed humps are intended to be smooth and comfortable for average sized vehicles at a speed of 32-40kmph (20-25mph). The design of speed humps consists of a circular-arc cross-section with a chord length of 3.7m (12ft), which extends 75mm (3in) above the pavement surface at the center. The 85th percentile speed for street with speed humps is 40kmph (25mph) with the average speed is typically under 32kmph (20mph). (*37*) Disadvantages of speed hump include an increase of noise and some find the humps or the associated warning signs unattractive. Drivers have been viewed driving with two tires in the gutter to minimize the effect of the humps. (*37*)

Speed humps affect different types of vehicles in different ways. Large vehicles such as trucks, buses, and emergency vehicles can "bounce severely" while cars navigate the humps with little or no trouble. A Danish study reports the use of "K-Humps" which are speed humps with two cross-sections. The characteristic speed hump dimensions are provided at the center of the lane and a wider section is provided at the edges of the lane. Cars will be influenced by the typical cross-section while the larger vehicles having a broader wheelbase will be subject to the wider cross-section. The wider cross-section will be less jolting to the large vehicles.

A similar idea has been used in the United Kingdom. The "speed cushion" is a hump, which has its full height only at the center of the lane. The height tapers until it is flush with the surrounding pavement. Larger vehicles wider wheelbases will travel over shorter, more comfortable cross-sections. (*70*)

ITE's 1997 *Guidelines for the Design and Application of Speed Humps—A Recommended Practice* lists the following restrictions of the proper usage of speed humps. (*75*)

- Streets classified as "local".
- No more than two travel lanes or 40-foot pavement width.
- Horizontal curve of 300-foot radius or more.
- Vertical curve with adequate stopping sight distance.
- Grade of 8 percent or less.
- Posted speed limit of 30 mph or less.
- No more than 5 percent long-wheelbase vehicles.
- Not on primary emergency response route or bus route.
- Majority of residents support.

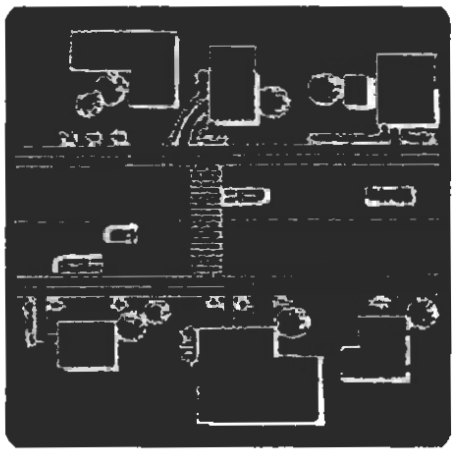
Source: ITE Traffic Engineering Council Speed Humps Task Force, *Guidelines for the Design and Application of Speed Humps—A Recommended Practice*, Institute of Transportation Engineers, Washington, DC, 1997, pp. 8–10.

Speed bumps are not recommended for street use because they are designed for speeds of only 8-16kmph (5-10mph). (*37*)

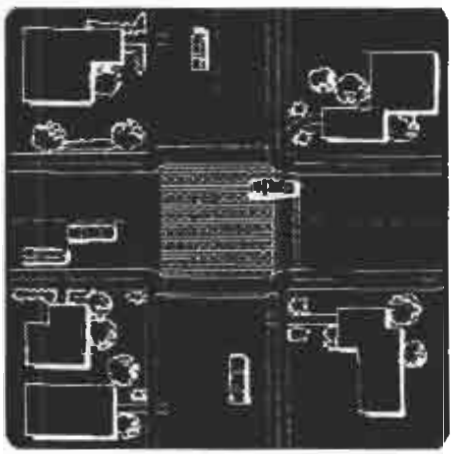
A speed table is similar to a speed hump with the exception of a flat surface at the top of the cross-section. This flat section often has a brick or other textured surface. The raised crosswalk is a specialized version of the speed table. Markings and signs distinguish the table as a pedestrian crossing. Raised intersections call attention to the intersection and slow vehicles at the most critical portion of the street, which can make avoiding a collision easier. However, raised intersections may make turning maneuvers more difficult. Textured pavements are usually stone or brick. This treatment produces a slightly bumpy ride on an extended section of the street while increasing the aesthetics of area.

Reducing Volumes

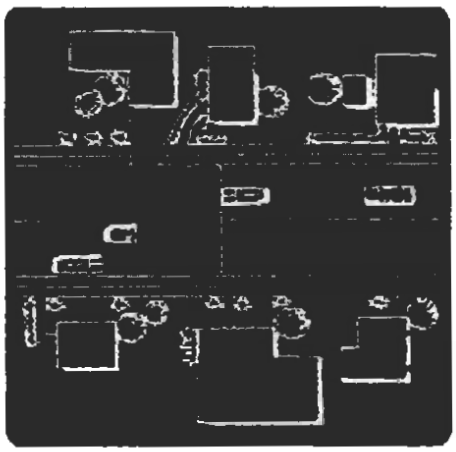
Local streets are sometimes used as short cuts by through traffic. This can create an unsafe situation on roads not intended for this purpose and local residents especially suffer.



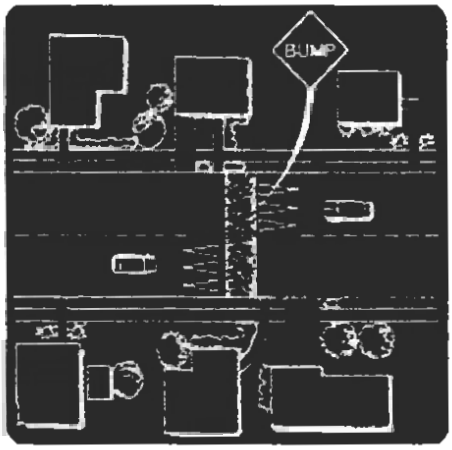
Raised Crosswalk (3-12a)



Raised Intersection (3-12b)



Speed Table (3-12c)



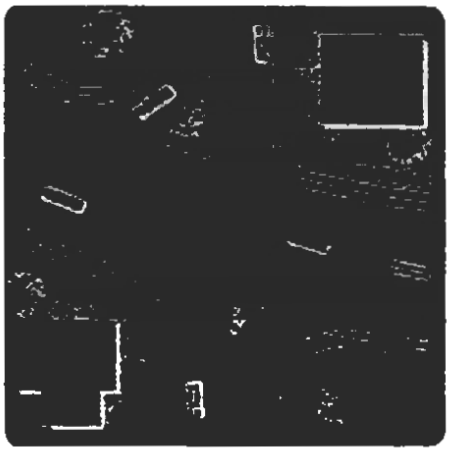
Speed Hump (3-12d)

Textured Pavement (3-12e)

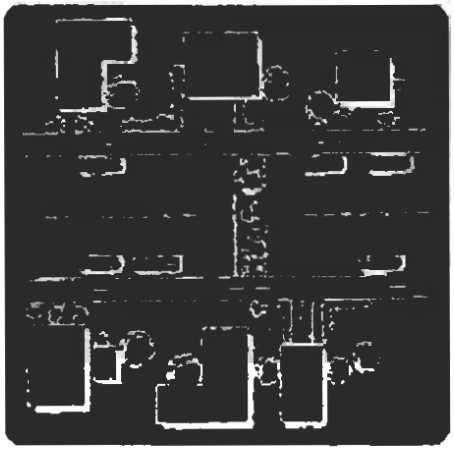
SOURCE: www.trafficcalming.org

Figure 3-12a-e: Traffic Calming by Tactile Treatments

Diagonal Diverter (3-13a)

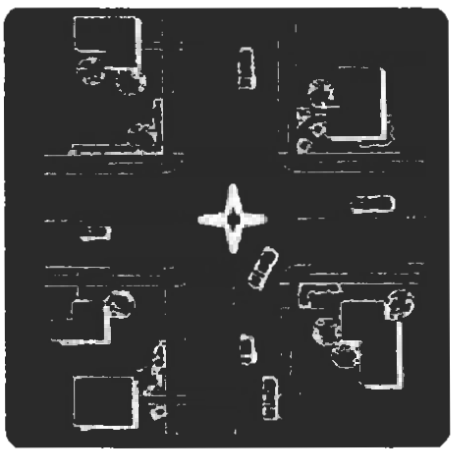


Forced Turn Island (3-13b)

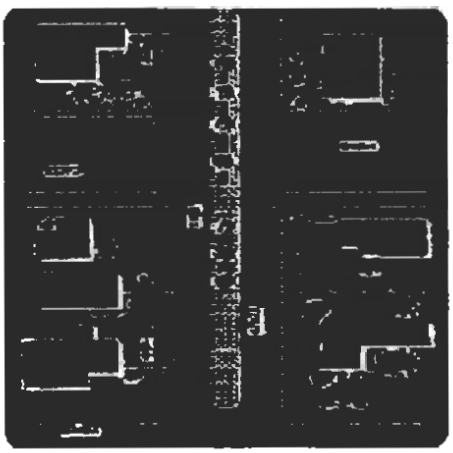


Full Closure (3-13c)

Half Closure (3-13d)



Star Diverter (3-13e)



Median Barrier (3-13f)

SOURCE: www.trafficcalming.org

Figure 3-13a-f: Traffic Volume Reduction Treatments

Figures 3-13a-f are examples of methods of reducing traffic volumes on local streets. All of these methods restrict the choices in movements of the traffic. These attempts to discourage non-local cut-through traffic by creating an inconvenient path.

Diagonal diverters also known as full diverters, or diagonal road closure (Figure 3-13a) are positioned at intersections. The diagonal barrier prevents through traffic and reduces the possibilities of conflicts. Vehicles are forced to make a ninety-degree turn. Pedestrian safety is improved. The barrier provides a possible location for landscaping and can include a bicycle pathway. Local residents may be inconvenienced and emergency vehicle response times could be adversely affected.

The forced turn islands (Figure 3-13b) also known as forced turn channelizations, pork chops, or right turn islands restrict certain turning movements.

Full closures (Figure 3-13c) also known as dead ends, or cul-de-sacs are barriers that eliminate all through traffic. Typically only the sidewalk is left open. Half closures (Figure 3-13d) also known as partial closures, or one-way closures restrict entrance (with the exception of bicycles) at the intersection of a local street while allowing two-way traffic on the majority of the street. Both types of closure may inconvenience locals and especially the full closure could hinder emergency vehicles.

Star diverter (Figure 3-13e) allows only right turns at an intersection, discouraging cut-through traffic.

A median barrier (Figure 3-13f) also known as median diverter, or island diverter is a center island continuing through a four-legged intersection limiting the possible vehicle movement options.

Unsuccessful Attempts at Traffic Calming

Some early attempts at traffic calming in this country have proven ineffective for several reasons. People often disregard posted speed limits and drive at a rate perceived as comfortable, which typically is a function of the roadway design. When traffic control devices are misused or unwarranted, generally they do not receive appropriate respect by the motorists and are sometimes ignored. Additionally, where vehicles have been slowed excessively, there has be a trend of the motorists accelerating between controls to recover time.

SCHOOL ZONES

Younger pedestrians are at a greater risk than other pedestrians due to their size and the unpredictable nature of their movements. Pedestrians under the age of 15 are twice as likely to be involved in a collision as other pedestrians. The most common group for child pedestrian collisions is from ages 5 through 8 years. However, the student's trip to school is generally safer than other pedestrian activities with which the child is involved. (*32,37,50*)

Children have difficulties judging adequate gaps in traffic and estimating appropriating vehicle speeds. Other factors that contribute to the problem are due to a child's lack of attention to surroundings and underdeveloped peripheral vision at this age. Children also have limited experience and understanding of crosswalks and traffic control devices. An additional aspect affecting safety is the smaller stature of

children that make them more difficult to be detected by drivers. (*33,37,50*) Research has found that adults uniformly misjudge the abilities of a child to function in traffic. (*31*)

The main types of collisions involving child pedestrians include darting out in front of traffic, dashing through an intersection, crossing in front of a turning vehicle, crossing a multilane street, entering or crossing a roadway, playing in the street, going to or from a school bus, and crossing behind a backing vehicle. (*31*)

School zone policies, practices, and standards should be developed by engineering studies. Parents and others often have unrealistic demands for measures to counteract the potential problem of pedestrian safety in school zones. Experience has shown that requests concerning crossing control in school zones are often expensive, unnecessary, and decrease the respect for other warranted traffic control devices. Non-uniform traffic control devices can cause confusion and may lead to collisions. (*50*)

Pedestrian safety is dependent on both education of the pedestrians and motorists and respect and understanding of the traffic control devices.

There are two components for providing safe walking routes for school children. The first is the physical facilities and the second is an operational plan. Walkways and sidewalks are the main facilities that serve the purpose of physically separating the young pedestrians from the motorized traffic. The operations plan is comprised of the traffic control devices and the supervision/control to ensure increased safety for student pedestrians.

Physical Characteristics

Schools should have an easily accessible vehicle entrance to reduce congestion on the adjacent street, which could contribute to pedestrian collisions. Wider sidewalks or separate bikeways and sidewalks may be appropriate in heavy pedestrian areas near schools. Vertical separation of these facilities by curbs and horizontal separation by buffers or ditches from motorized traffic are strongly encouraged for school routes by the 1997 *Pedestrian Facilities Guidebook*. (*31*)

The school facility should provide separate parking for teachers, students, and visitors, while bus loading areas should be separated from all other traffic. Pedestrians should not be required to cross parking lots. Driveways should be located in the best feasible location as to decrease the number of pedestrians that must cross them. (*50*)

Parking restrictions at driveways and crossings should be implemented to increase the visibility of the pedestrians. Fencing or other pedestrian barriers can help channelize the pedestrian path to appropriate crossing locations. Street lighting should also be reviewed in school areas. (*50*) Table 3-17 outlines elements of good school site design.

Table 3-17: Elements of Good School Site Design

• Surrounding streets are equipped with sidewalks and bike lanes. • The building is accessible to pedestrians from all sides (or at least, from all sides with entries/exits). • Trails and pathways provide direct links between the school site and the surrounding neighborhoods. • Bus drop-off zones are separated from auto drop-off zones to minimize confusion and conflicts. • Buses, cars, bicycles and pedestrians are separated and provided with their own designated areas for traveling. • Pedestrian travel zones (sidewalks, etc.) are clearly delineated from other modes of traffic (through the use of striping, colored and/or textured pavement, signing and other methods). • Parking is minimized; people are encouraged to walk to school. • Pedestrians are clearly directed to crossing points and pedestrian access ways by directional signing, fencing, bollards or other elements. • Strategically located, well-delineated crossing opportunities are provided, including marked crosswalks at controlled intersections and mid-block crossings (signalized if warranted). • Traffic calming devices (raised crossings, refuge islands, bulb-outs at crossings, on-street parking, traffic circles, landscaping, etc.) are installed in the vicinity to slow vehicles.

SOURCE: *1997 Pedestrian Facilities Guidebook* (WSDOT)

Operations Plan

Each school should construct a program that contains a safe walking route to school. Existing traffic controls should be reviewed and used where sufficient. In addition, deficient areas should be identified and improved. The ITE *Recommended Practice –School Trip Safety Program Guidelines* lists the following six steps in developing a school program (*76*):

1. Set up the school trip safety process.
2. Identify deficiencies in routes.
3. Designate route maps for safe routes to school.
4. Select route improvements and control measures.
5. Implement route improvements.
6. Evaluate routines periodically.

All safe routes to school should provide sidewalks and walkways. Crosswalks may be helpful in directing students to suitable crossing locations. If adequate crossing gaps do not occur at major streets, traffic signals should be considered. Individual locations should be studied to ensure the most appropriate traffic control devices are provided. The evaluation should include geometric factors, collision data, vehicle speeds, pedestrian and vehicular volumes, and age of the children.

A committee at the local level should be responsible for ensuring that school crossing measures are appropriate. Members of the community representing organizations such as the parent-teacher association, police, school, engineering department, mayor's office, etc. should be involved with this committee.

The principal or other representative from the school district should be informed of any changes in the traffic control or construction projects in the school zone area even if the school is not directly affected.

Traffic Controls at School Crossings

School Advance warning signs should be placed at school zone boundaries and before school crossings.

Traffic signals, which are installed under the School Crossing Warrant, should be coordinated with adjacent signals to minimize the traffic disruption. Pedestrian signals and push-button actuation should be included with the installation. Crosswalks should also be provided. Some locations will also require a crossing guard, particularly where younger children will be the users.

The maximum speed limit by Washington State law in school zones is 32kmph (20mph). This limit must be extended 91m (300ft) in each direction from the school and marked school crosswalks. It is also recommended that the speed limit be reduced further where special circumstances exist and an engineering study has deemed this action appropriate. (*31*)

Flashing beacons are commonly used as supplemental control devices in school zones. They are often mounted to speed limit signs and are activated during the portion of the day children are present or at overhead crosswalk signs for the purpose of advance warning to a potential hazard. However, the effectiveness of flashing beacons has been in question. Studies have shown that the motorists become accustomed to seeing flashing beacons and stop giving attention to the warning. (*31*)

A study published in the November 1999 issue of the *ITE Journal* found that school zones with the presence of a flashing beacon, with the words stating the speed limit is in effect while flashing, mounted to the speed limit sign did contribute to a reduction in speeds when the approach speeds were 56kmph (35mph). This treatment was compared to zones with the same approach speed which had two other types of posted signs: 1) the school speed zone limit was in effect when children present, and 2) the school speed zone limit was in effect during specific times (i.e. 7:30 AM to 4:30 PM). The beacon did not have a significant effect when the approach speeds were 40kmph (25mph). This study was conducted in the state of Washington where all school zone speed limits are 32kmph (20mph). (*77*)

Another finding of this study was that motorists were more likely to comply with the school zone speed limit when the approach speed was 40kmph (25mph) rather than 56kmph (35mph). (*77*)

Currently a test program is being conducting by the Federal Highway Administration concerning the use of an alternate sign color for school zones. Florescent yellow-green signs are replacing the traditional yellow warning signs use in school zones. The expectation is that the new color will direct more attention to the warning message on display. (*31*)

One report from the Portland, Oregon, Bureau of Traffic Management suggests the transfer of marked school crossings from intersections to mid-block locations. This will reduce the complexity of the crossing maneuver for the student pedestrians. At mid-block crossings, fewer vehicle movement options are available, therefore creating a simpler situation. (*78*)

An in-pavement lighting system has been developed for school zones. The flashing light fixtures are installed down the centerline of the roadway in school zones. An amber light is emitted and aimed towards the two directions of traffic. The flashing lights are set by timer to flash for one hour before the start of school and for one hour after school when children will be present. Typical installation is for fixtures to be located between 10.7-15.2m (35-50ft) apart. The lights can be seen at more than 183m (600ft). (*79*)

Traffic Calming in School Zones

Traffic calming may also be an effective action for increasing safety and comfort for pedestrians in school zones. This treatment is typically most appropriate for local access streets in residential areas. Some suggested examples by the 1997 *Pedestrian Facilities Guidebook* of traffic calming techniques that may be beneficial in school zones are raised crossings, refuge islands at crossings, traffic circles, chicanes, bulb-outs, speed humps, narrower streets, on-street parking, trees and landscaping along right-of-way, and gateways. (*31*) These traffic-calming techniques are fully described and discussed in the previous Traffic Calming section of this report.

Crossing Guards

Sixty-six percent of children will use unsignalized marked crosswalks and 83% will use signalized marked crosswalks, but nearly all children will use crosswalks when a crossing guard is present. At signalized intersections, only 65% of school children will cross during the green phase when unassisted. Nearly all students will cross during the green phase when activated by an adult crossing guard. Most motorists do not reduce their speed in school zones unless there is a perceived risk such as a policeman, crossing guard, or visible children. (*32*)

School crossing guards should be considered in special situations in which additional supervision can assist children in safely crossing the street at dangerous locations. The two main functions of a crossing guard are to assist students in crossing the street safely and assist teachers and parents in educating children regarding safe crossing behavior. For insurance and dependability reasons, the crossing guard should be a trained and paid employee as opposed to a volunteer. Crossing guards should be provided (and carry) identification cards, a list of responsibilities, and list of emergency phone numbers.

Florida Statute, section 234.302 requires that all crossing guards become state certified and retrained annually. Crossing guard trainers must complete a twelve hour course which covers (*37*):

- Florida School Crossing Guard Training Guidelines;
- Florida/National Pedestrian /Bicycle Crash Statistics;
- crash causation;
- visibility and conspicuity;
- traffic control devices including the "WALK", flashing "DON'T WALK", and steady "DON'T WALK".
- purpose, goals and responsibilities of the school crossing guard;
- limitations of children in traffic;

- public image;
- uniforms;
- legal /risk management aspects of the job; and
- most importantly, the standardized procedures for conducting a school crossing.

The crossing guard trainer then is qualified to conduct crossing guard training which is mandatory for certification. This training consists of a four-hour classroom training, two-hour in-the-field-training, and two-hour on-site observation. There is no cost for the training. (*37*)

An engineering study should be conducted for the appropriate placement of a crossing guard. A traffic engineer and school principal or school district transportation director should make decisions jointly concerning the appropriate locations for crossing guards.

The following are some recommended guidelines for the locations of an adult crossing guard (*32,50*):

- Uncontrolled marked crosswalks located at least 180m (600ft) from a controlled crossing at:
    1) Rural Areas—at least 30 crossing students and 300 vehicles per hour for each of any two one-hour crossing periods per day.
    2) Urban Areas—at least 40 crossing students and 350 vehicles per hour for each of any two one-hour crossing periods per day.
    Note: Locations where the speed limit is greater than 60 kmph (40mph) rural area criteria should be used.
- Stop sign controlled locations where vehicle volumes exceed 500 vehicles per hour at any period when children walk to or from school
- Traffic signals with high numbers of crossing students and vehicular turning volumes or wide streets:
    1) At least 300 turning movements per hour through the school crosswalk while children are going to or from school.
    2) Unusual circumstances—i.e. the crosswalk is over 80ft in length with no refuge island or large volumes of commercial traffic.

The Washington Administration Code 392-151-030 restricts the use of both adult crossing guards and student safety patrollers to locations with minimum traffic control. This control must at least consist of school warning signs, a marked crosswalk, and posted speed limit signs. (*31*)

School Safety Patrol

Another program to increase and encourage student pedestrian safety is the school safety patrol. Patrol members consist of individuals from the student body. The members should be selected from the upper grades (below fifth grade is not recommended) and possess leadership skills and reliability. Patrol membership should be voluntary and open to all who meet the qualifications. The individual schools should administer each program with the policies determined by the principal. (*37*)

OLDER AND DISABLED PEDESTRIANS

Pedestrians with Special Needs

The United States is home to 43 million people with some type of disability. Disabilities can be temporary or permanent in nature. Age, illness, injury, and pregnancy are examples of causes that can introduce a disability to a previously agile body. It is estimated that 70% of Americans will experience some disability in their lifetime—temporary or permanent. (*31*)

The abilities of pedestrians vary widely, but all are entitled to the access of public facilities. For the purposes of traffic engineering, disabilities can be classified into three types—mobility impairments, sensory deficits, and cognitive impairments. Individuals may exhibit one or more of these types of impairments and to varying degrees. (*32,37,50*)

Mobility impairments include people with limited movement abilities and deficiencies in stamina and balance. The use of canes, crutches, wheelchairs, walkers, and braces sometimes aid persons with this type of disability. Pregnant women are also included in this group.

The sensory deficit type of disability covers not only blindness and deafness but also partial deficiencies of vision and hearing which are more common. Color blindness also fits into this category and can especially be a problem when the recognition of the colors red and green are affected.

The third category of disability is cognitive impairment. In the United States people who cannot read or understand English are considered to be cognitively impaired, as well as the more commonly considered mental retardation and learning disabilities such as dyslexia.

The Veteran's Administration determined that wheelchair users are required to exert 30% more energy than fully abled pedestrians for the same route. It was also found that 70% more effort is required for pedestrians using crutches or artificial legs. (*32,37*)

Americans with Disabilities Act (ADA)

July 26, 1990, the Americans with Disabilities Act (ADA) was signed into law. The ADA is a civil rights law and ensures the rights of the disabled to the access of public facilities including transit and public buildings. All new and retrofitted public facilities must be accessible to disabled persons. Several sources state that it is equally important to comply with the law specifications as well as the spirit in which the act was intended. (*32,37*)

The ADA made it illegal to discriminate against disabled persons. Construction of facilities and alteration of facilities that are not accessible to disabled persons is considered discrimination. In addition, any government program not accessible to the disabled is also discriminatory. (*80*)

Facilities funded at least partially by federal funds must comply with the Architectural Barriers Act of 1968 and the Rehabilitation Act of 1973. Both of these acts prohibited the discrimination against disabled persons.

All new local and state facilities bid after January 26, 1992, must be designed and constructed for accessibility. Alterations to existing local and state facilities must provide modifications to make the facility accessible to the disabled.

In cases where a facility was constructed before January 26, 1992 and no modifications have been made, 'program access' must be provided. Disabled persons may not be restricted from accessing government programs. For example local governments, for the benefit of citizens, provide pedestrian facilities such as sidewalks, crossings, and shared use paths. These facilities that constitute a government program must be generally available but are not subject to the new construction or alteration standards.

Compliance with ADA and Overview of Considerations

The ADA instructs that public facilities must be accessible to the disabled population. The ADAAG for public right of ways has been accepted into law. Consequently, it is clear that the ADAAG must be followed and during the planning of sidewalks the following design elements should be developed with the consideration of access for the disabled in mind (*81*):

- Grade—Steep grades should be avoided wherever possible. Resting platforms should be provided when steep grades are present. Maps should direct pedestrians to routes with gentler grades and signs warning of upcoming steep grades.
- Width—Sufficiently wide sidewalks allow passage of wheelchairs and pedestrians aided by walkers even with the presence of street furniture and utilities.
- Vertical Clear Space—Overhanging obstacles are potential hazards to the visually impaired and contribute to difficulties encountered by those with mobility impairments. Regular maintenance can help to combat this potential hazard.
- Small Changes in Level—Differences in the height of adjacent pavements can cause pedestrians with and without mobility impairments to stumble and prevent the passage of wheelchairs. Regular assessment of sidewalk conditions, prompt attention to problem locations, and confining the roots of newly planted vegetation can help alleviate this problem.
- Driveway Crossings—Poorly designed driveway crossings that extend through a sidewalk can create a cross-slope difficult for the mobility impaired to retain their balance while traversing. Wheelchairs can be propelled into traffic by the steep cross slope. Providing a level section for the pedestrian traveled way between the sloped property and the sloped section extending from the gutter is one solution.
- Curb Ramp Design—A balance between a gentle slope which is easy for mobility-impaired pedestrians to maneuver and slope, which physically indicates to visually impaired pedestrians that an intersection location has been reached. Level landings should also be provided.
- Curb Ramp Placement—At intersections one diagonal ramp located on the corner can serve the two crosswalks, however, two ramps each directed into a

crosswalk are better for safety. One curb ramp is less expensive, particularly when the project is a retrofit. The users are not directed outside the crosswalk.

- Rapidly Changing Grades—Changes in grade, particularly a relatively steep down slope meeting a relatively steep up slope can be problematic to wheelchairs. Roads that have been periodically resurfaced by the addition of asphalt layers that have a large crown can be milled to help in some situations.
- Warning Cues—The visually impaired can have difficulties accessing when the pedestrian environment is changing. Tactile cues such as truncated domes or warning grooves have been used at intersections, transit platforms, and potentially hazardous sites. Most visually impaired pedestrians are not completely blind and can recognize color contrasts. Shades must be chosen to be visible to the color blind. Contrasting building materials can be used.
- Orientation Cues—Cues can convey information about location relating to surroundings. Corners should have the smallest radius feasible to help with orientation. Audible pedestrian signals use different tones for the walk phase for the north/south direction and east/west direction.

The state of California makes every effort to comply with the federal ADA and the State Title 24, in making appropriate interpretations for use on California state highways.

Sidewalks

The absence of sidewalks is particularly hazardous for the disabled. These users can benefit from physical separation provided by curbs and buffers. Sidewalks should be constructed in all urban areas, non-interstate public highway rights-of-way, commercial areas accommodating the pubic, and between all transportation stops and public areas. (*32*)

The needs of wheelchair users and others with a disability must be considered in the overall design of sidewalks and curb ramps. The surface should possess the minimum necessary cross slope for proper drainage with a maximum 2% slope. Greater slopes require more effort by wheelchair users and people on crutches to continue on a straight path. The grade of the sidewalk should not be greater than 8% and 5ft level resting areas should be positioned if a steep grade extends more than 9.1m (30ft). Alternative routes should be available when steep grades are unavoidable. Handrails are required on long ramps as some people with disabilities depend on them for support and wheelchair users pull themselves along the ramp.

The surface of sidewalks, "the roadway of the pedestrian" as described by the 1998 ITE *Design and Safety of Pedestrian Facility* should be paved with a relatively smooth, durable material and be of adequate width to accommodate expected volumes of pedestrian traffic. Sidewalks should not have any section with an unobstructed width less than 0.9m (3ft). This is the minimum width a wheelchair user can pass. Sidewalks preferably should have a minimum clear width of 1.5m (5ft).

Street Furniture

Obstacles on sidewalks, such as street furniture, can be hazardous to pedestrians with disabilities. The Design and Safety of Pedestrian Facilities lists the following guidelines to consider for the placement of street furniture:

- All street furniture overhanging a pedestrian path should be at least 200cm (80in) above the ground.
- All objects mounted to a wall or post, or standing alone should not have an open space higher than 69cm (27in) off the ground.
- All objects mounted to a wall above 69cm (27in) should not extend outward more than 10cm (4in).
- All protruding objects must not extend into the 91cm (36in) clear width reducing the useable path. Objects in this area can be especially hazardous because blind pedestrians will be unable to detect these obstacles with their cane.

Parking

People aided by wheelchairs, leg braces, or artificial legs often must fully open the car door to enter and exit the vehicle. Furniture and other obstacles should be positioned away from the area required for access.

Disabled parking spaces should allow at least 3.9m (13ft) width to accommodate vans containing lift equipment. A minimum clear width should be 1.5m (5ft) to allow space for unloading.

The slope provided for disabled parking should not exceed 2%. A greater slope can cause extreme difficulties in stability for wheelchair users that must lift themselves into the vehicle.

Wheelchair users should not be forced to travel behind parked vehicles enroute to exiting the parking lot. Collisions involving backing vehicles are a problem in parking lots and the wheelchair users are at an additional disadvantage being more difficult to see because of their reduced height.

Curb Cuts and Ramps

Those in need of using the curb ramps should not be expected to change direction after descending the ramp. Two ramps should be positioned at corners to allow straight access to the crosswalk or one center ramp may be adequate if sufficiently wide to permit users to descend in the same direction as the crosswalk. Refuge islands should either be equipped with ramps or cut-throughs at marked and unmarked crosswalks.

All ramps should be at least 1m (3ft) in width to satisfy the dimensional requirements of a wheelchair. Also the bottom portion of the ramp that extends to the street should flare. A drop off of even 6.4mm (0.25in) is capable of causing a wheelchair to tip over. The newer sport-type and lightweight models, many of which possess shorter wheelbases, compound the problem of wheelchair instability. Some power wheelchairs have battery packs in the front portion of the chair. In these situations, minimal drop offs are also critical. (*32*)

The flared side sections should not exceed a slope of 10%. Tactile warnings should extend the full width and length of ramps.

Proper drainage is essential for the safety of disabled pedestrians. Drop offs, potholes, and uneven surfaces can be hidden under standing water. In colder regions, ice can form in areas of poor drainage, reducing the traction.

Signing

Signs consisting of symbols should always be used over word messages, where possible, for the accommodation of illiterate and non-English speaking people.

High contrast colored signs and including the spelling of the color word can be essential when a route or entry is color coded.

Grade-Separated Structures

Facilities that encourage increased safety of pedestrians must also be accessible to the disabled. When mechanical devices are included to serve the disabled, priority should be given to keeping the system in good working condition. At-grade crossings, where grade separated crossings exist, can be particularly hazardous because drivers do not expected pedestrians to cross at these locations.

Accessible Pedestrian Signals

In the 1999 *Access to Intersection Traffic Control Information,* by The American Council of the Blind, a definition was provide for accessible pedestrian signals, "Accessible pedestrian signals provide information in non-visual format, which includes audible tones or verbal messages, and/or vibro-tactile information." (*80*)

Accessible pedestrian signals have diverse characteristics.

The crossing maneuver is complex for the visually impaired. All of the following steps must be successfully completed for a safe crossing (*82*):

1. Detecting the street
2. Identifying the street
3. Analyzing intersection geometry
4. Analyzing traffic control system
5. Identifying crossing interval
6. Starting the crossing
7. Maintaining crossing alignment

There is some evidence that the redundancy of information due to audible signals for the non-visually impaired may contribute to a reduction in pedestrian vehicle conflicts. Also, experience in European countries has led to the belief that pedestrians tend to cross more promptly at crossings with audible signals which necessitates a shorter crossing interval. Pedestrians with cognitive difficulties may also benefit from audible signals. (*82*)

In *Accessible Pedestrian Signals*, eleven specific products on the market are described by the following nine characteristics (*83*):

- Type of device: speaker mounted in pedestrian signal head, transmitter mounted in pedestrian signal head, or push button integrated
- Audible sound: voice, bell, buzzer, birdcalls, ticker, or tones
- Volume: fixed, variable by the installer, automatically varies according to surround sound level, variable by user, or audible only at user request

- Presence of locator tone to direct user towards pushbutton
- Presence of special tone indicating beginning of walk interval
- Presence of vibrating sidewalk
- Actuation feedback: light or tone indicating pedestrian call has been registered
- Tactile element: arrow indicating the direction a push button is functional or tactile information about intersection geometry
- Street name information

In some countries all newly installed pedestrian signals must be of the audible type. In the U.S. individual requests must be made along a specific route for the installation. (*84*)

The City of San Francisco has installed infrared transmitters called "talking signs" at several intersection locations to transmit audible messages to visually impaired pedestrians equipped with hand-held receivers. The audible message identifies the location, travel direction, and the name of the street to be crossed, in addition to real time information about the pedestrian signal indication. The "talking signs" are less intrusive than the "Cuckoo" and "Peep-Peep" noises and provide helpful information at irregular shaped intersections. The City of San Francisco Department of Parking and Traffic has worked closely with the manufacturer regarding this technology. Currently the transmitters are added to existing pedestrian signal heads. (*68*)

Augusta, Georgia has installed two audible pedestrian signals near a VA Hospital with a visually impaired rehabilitation center. A locator tone directs the visually impaired pedestrian towards the signal button. Brail instructions are located on the front of the signal. A chirping noise confirms that the call message has been received. The locator tone resumes until the crossing phase begins. At that time a voice states, "Walk light on to cross Wrightsboro Road." A different tone indicates the flashing "DON'T WALK" indication. This location is also equipped with a vibrating indication, which varies the frequency of the vibration according to the crossing phase to aid pedestrians who are both visually and hearing impaired. (*85*)

OTHER CONSIDERATIONS

Addressing Specific Types of Collisions

Table 3-18, found on the following page, suggests engineering and physical countermeasures to address specific types of pedestrian collisions. Dartouts (when a pedestrian suddenly attempts to move partially across the roadway) and dashes (when a pedestrian suddenly attempts to move across the roadway), at both intersection and mid-block locations, combined account for the majority of pedestrian collisions. (*91*)

Table 3-18: Matrix of Pedestrian Collision Countermeasures

Countermeasures / Accident Type	Engineering and Physical																						
	Barrier: Median	Barrier: Roadway/Sidewalk	Barrier: Street Closure	Bus Stop Relocation	Crosswalk: Intersection	Crosswalk: Midblock	Diagonal Parking-1 Way Street	Grade Separation	Facilities for Handicapped	Lighting: Crosswalk	Lighting: Street	One-Way Streets	Retroreflective Materials	Safety Islands	Sidewalk/Pathway	Signal: Ped. (Shared)	Signal: Ped. (Delayed)	Signal: Ped. (Separated)	Signal: Traffic	Signs and Markings	Urban Ped. Environment	Vehicular Traffic Diversion
Dart-out (First Half)	●	●				●	●														●	●
Dart-out (Second half)	●	●				●	●					●		●							●	●
Midblock Dash	●	●				●								●							●	●
Intersection Dash					●			●		●	●			●			●	●		●		
Turn-Merge Conflict								●									●	●				
Turning Vehicle								●									●	●				
Multiple Threat								●		●	●					●	●	●	●		●	
Bus Stop Related				●																	●	
School Bus Stop Related				●																		
Ice Cream Vendor																				●		
Trapped					●			●						●		●	●	●				
Backup																						
Walking on Roadway		●									●		●		●					●		
Result Vehicle-Vehicle Crash																				●		
Hitchhiking											●		●									
Working in Roadway																				●		
Disabled Vehicle Related																				●		
Nighttime Situation										●	●		●									
Handicapped Pedestrians									●													

SOURCE: *Safety Effectiveness of Highway Design Features*, Volume VI-Pedestrian and Bicyclists. Zegeer, Stutts and Hunter

Maintenance of Pedestrian Facilities

Pedestrian facilities must be properly maintained to provide a safe, accessible, and comfortable route for users. Typical concerns that should be addressed for timely maintenance are uneven pavements, puddle water, overgrown vegetation, sidewalk clutter, and snow covered walkways. Damaged pedestrian amenities, damaged or missing signs, improperly functioning signals, and worn pavement markings can create a hazardous environment.

The National Center for Bicycling and Walking website lists seven strategies for the implementation of maintenance improvements:

1. Identify key implementers.
2. Review existing policies and practices.
3. Review result in field and solicit comments from users.
4. Recommend appropriate changes in policies and practices.
5. Create an on going spot improvement program.
6. Evaluate progress.
7. Develop an inspection and maintenance checklist.

Maintenance checklists will vary by region and climate. Figure 3-14 is a sample checklist.

INSPECTION AND MAINTENANCE CHECKLIST

- ❑ **Uneven pavement and pavement with missing pieces:** Sections of walkway with a vertical pop-up of greater than 13 mm (1/2 in) should be replaced or repaired with a temporary asphalt shim. In locations with a high volume of pedestrian traffic, especially wheelchair users, the pop-up should not exceed 6 mm (1/4 in).
- ❑ **Snow and ice buildup on walkways:** Walkways should not be used as snow storage areas for snow removed from streets. Local policies should treat the clearance of snow from walkways as being of equal importance with clearing snow from streets. In areas where abutting land users are responsible for clearing walkways, local regulations should be enforced. Curb ramps should be kept clear of snow accumulation from plowing.
- ❑ **Expansion and construction joints have separated, creating a space between adjoining sections that is greater than 13 mm (1/2 in):** The gap can be filled with hardening expansion compound.
- ❑ **Loose sand and debris on the surface of the walkway:** Have the walkways swept and the debris removed. Where the abutting land user bears this responsibility, enforce local regulations to clean walkways.
- ❑ **Newspaper stands, portable signs, and other devices are creating barriers in a walkway:** The responsible parties should be required to remove the obstructions.
- ❑ **Tree roots that crack and heave walkways:** Have the failed sections removed, the roots cut and new sections of walkway installed. If the roots to be removed are large, contact an arborist to avoid injuring the tree.
- ❑ **Overgrown trees, shrubs, grass, or weeds are encroaching on walkways:** Local regulations that require abutting land users to perform timely clearance of vegetation that becomes an obstruction and/or limits sight distance should be enacted and enforced. As an alternative, private contractors can be hired to clear walkways and the costs assessed to abutting land users.
- ❑ **Transition problems resulting from previous repairs:** Where the pavement surface from a prior repair has deteriorated, become cracked, or is missing altogether, remove the transition section and have all defective sections of pavement replaced.
- ❑ **Worn or slippery steps or ramp surfaces:** Steps and ramp surfaces that have become worn and slippery should be overlaid, texturized, or replaced to create a slip-free and unbroken surface.
- ❑ **Worn paint on stop bars and crosswalks:** Develop a policy for regular inspection and refurbishment of paint on crosswalks and stop bars.
- ❑ **Missing or damaged signs:** Periodically check for missing or damaged signs and other traffic control devices.
- ❑ **Improperly functioning pedestrian signals:** Inspect pedestrian signals periodically for proper operation; clean lenses and replace bulbs as necessary.

SOURCE: The National Center for Bicycling and Walking

Figure 3-14: Inspections and Maintenance Checklist

Pedestrian Considerations in Work Zones

The MUTCD 2000 states that an experienced and/or certified person should apply all work zone traffic control provisions and do so only after an assessment and engineering judgment of the conditions.

Alternate Pedestrian Routes at Work Site

Alternate pedestrian routes should be provided where a work site interrupts existing pedestrian routes. The detoured route should be wheelchair accessible, free of debris, dust, holes, and mud, and as direct and safe as possible. Parking lanes may be used as temporary pedestrian walkways at construction sites when present. (*50*)

Pedestrians should be expected to pass through most work zones. Consideration of pedestrian access to crosswalks and bus stops is necessary. Advance warning of sidewalk closures must be visible to pedestrians. Where a sidewalk will be closed at a mid-block location, signs should be posted at adjacent designated pedestrian crossing. This signing will direct pedestrian traffic crossing the street to use an open sidewalk. People will not care to walk back to a previously passed intersection or crossing and may be tempted to cross at an inappropriate or hazardous spot. (*45*)

The needs of disabled pedestrians must also be considered in work zones and adequate accommodations should be determined by an engineering study. The disabled require more even and smoother surfaces, gentler slopes, and wider pathways for an accessible route. (*45*)

Temporary separate walkways should be provided when pedestrians are forced to pass through or around a work zone restricting the usual pedestrian route. Work site equipment should not cross the pedestrian path when possible. This would create risks of conflicts and create an uneven, muddy traveling surface for pedestrians. When the interruption of the path is necessary it should be controlled with flaggers and cones.

The MUTCD 2000 also lists three considerations in the planning of safe pedestrian routes through work zones. The following three items are those recommended (*50*):

- Pedestrian routes should not lead pedestrians into conflict with work site vehicles, work site equipment, and work site operations.
- Pedestrian routes should not lead pedestrians into conflict with traffic traveling through the work zone.
- Pedestrian routes should provide a safe and convenient route that reflects the positive attributes of the existing pedestrian walkways in the area.

Work Zone Pedestrian Barriers and Controls

The 1997 Planning and Designing Local Pedestrian Facilities form the North Carolina Department of Transportation states that the local engineer may approve traffic cones, barricades, and signs as means of separating pedestrians from the work areas and low speed vehicular traffic for short periods of time.

For longer-term work sites near high pedestrian traffic or near schools, it may be appropriate to provide a fence of height 2.4m (8ft) to discourage access into the site. (*50*)

In cases where the potential risk of falling debris around pedestrian routes occurs, covered walkways may be needed. The walkways must be sturdily constructed, provide adequate lighting for nighttime use, and be noticeable to traffic. External lighting or orange and white striping may be needed to aid the visibility of the covered structure to motorists. (*50*)

In work areas where pedestrians are at risk of being struck by vehicles, separation by longitudinal barriers should be provided. The ends of the longitudinal barriers facing traffic should be flared or protected. All work zone materials and controls must allow adequate sight distance at crosswalks and intersections. (*50*)

Temporary traffic control devices must be "crashworthy", not creating projectiles and minimizing other hazardous situations for pedestrians, motorist, and workers. (*45*) Wooden railings, chain link fences, or other similar barrier types are unacceptable in locations where high-speed traffic exists. (*50*)

All work zone materials and controls must allow adequate sight distance at crosswalks and intersections. (*50*)

Pedestrians on Bridges

Pedestrians, in addition to bicycles and vehicles, need bridges to cross barriers such as rivers, freeways, and railroad tracks. Many freeway over-crossings constructed during the 1950's and 1960's neglected the needs of pedestrians. Because of the associated expense and extensive lifespan of bridges, it is critical to consider pedestrian accommodation any time a new bridge is designed or retrofitted.

To address the pedestrian deficiencies, an inventory of existing bridges and available access for pedestrians should be developed. Bridges in need of major renovations should have additional documentation of pedestrian deficiencies for the purpose of adding pedestrian improvements when the project is scoped and funded. New bridges should have pedestrian provisions where appropriate.

In the case where bridges have adequate pedestrian walkways but insufficient pedestrian approaches, consideration should be made to add the needed approaches, possibly through annual walkway improvement programs.

To address the need for walkways on existing bridges not in line for renovation, a system has been developed to cantilever walkways from the side of existing bridges. This treatment is not always possible and the pedestrian improvements may be postponed until a renovation is made in the future. Pedestrian exclusive over-crossings are a possible solution. Several firms have developed prefabricated pedestrian bridges. It may also be possible to "recycle" an existing bridge marked for removal and relocate it.

An evaluation should be made involving the type and number of pedestrians using the improved facility. If pedestrians do not use the accommodations, reasons should be established. Additional improvements may be necessary.

Considerations for bicycle accommodations must be made in the process of designing pedestrian walkways. Shared use of walkways is not recommended by the AASHTO green book or the 1995 *Oregon Bicycle and Pedestrian Plan.* (*36,43*) It is not recommended that space be provided for bicycle travel on the roadway unless it is not feasible to separate the two modes. The design standards necessary for bicycle accommodation will likely exceed those for pedestrian travel only.

The 1995 *Oregon Bicycle and Pedestrian Plan* standards for the width pedestrian walkways on bridges is 2.1m (7ft) with a minimum width of 1.8m (6ft). This dimension includes a provision for the shy distance from the rail. Some pedestrians are uncomfortable walking close to a vertical drop.

The walkway may not be narrower than the approaches. When the approaches on either side differ in width, the smaller of the two may be used. A separation rail is required between the walkway and roadway when vehicle design speeds are in excess of 65kmph (40mph). (*49*)

Pedestrian Amenities

The National Center for Bicycling and Walking website lists the following pedestrian amenities that can make a walkway more inviting:

- Seats and benches
- Transit shelters
- Awnings
- Drinking fountains
- Restrooms
- Trash containers
- Telephones
- Information and directional signage
- Information kiosks
- Statuary
- Ornamental fountains
- Planters
- Grassy areas and planting strips
- Shade trees
- Textured walkway surfaces
- Walkway lighting
- Up-lighting of trees, monuments, and gazebos
- Selective relocation of utility poles and/or burial of utility cables

Benches should be located in shaded locations and an acceptable clear width must be maintained. Widening of the sidewalk may be necessary.

Transit shelters should be erected over paved stops and the stops should be connected by paved walkways. Three sides should be provided to the shelter for weather protection. Transparent materials should be used to reduce safety concerns. Lighting should be provided and the shelter should not block pedestrian through travel.

Awnings can provide weather protection and add to the aesthetics of the environment.

Landscaping can add to the pedestrian experience by creating a less stressful and less tiring feeling in pedestrians. (*86*) The choice of specific vegetation should consider maintenance, climate, growth patterns, roots, width of planting strip, and soil type.

Before and after surveys should be conducted and an evaluation should be made of the pedestrians' perception of the improvements by pedestrian amenities. (*86*)

Curbside Parking

On-street parking can affect the safety of pedestrians in different ways. Curbside parking narrows the roadway, which tends to slow vehicular traffic and may increase the safety of pedestrians. It also creates a physical barrier between traffic and

pedestrians. However, parked vehicles more often hinder the visibility between pedestrians and traffic creating serious safety issues. One of the most common types of pedestrian and vehicle collisions is the dart-out. This is where a pedestrian enters a roadway, usually a running child, and the motorist has inadequate time to avoid the collision. (*32*)

Restrictions on Curbside Parking

The 1998 ITE publication of *Design and Safety of Pedestrian Facilities* states most local jurisdictions set the following standards on parking:

No person shall:

1. *Stop, stand, or park a vehicle:*
    a. *On a sidewalk;*
    b. *Within an intersection;*
    c. *On a crosswalk;*
2. *Stand or park a vehicle, whether occupied or not, except momentarily to pick up or discharge a passenger or passengers:*
    a. *Within 6.1 m (20ft) of a crosswalk at an intersection;*
    b. *Within 9.1m (30ft) upon the approach to any flashing signal, stop sign, yield sign, or traffic-control signal located at the side of a roadway.*

There are additional conditions in which it can be advantageous to pedestrians to restrict curbside parking. These locations include where dart-out collisions are common, no sidewalk exists, sight distance is inadequate, and vehicles obstruct sight distance by parking too close to the crosswalk. (*32*)

Mid-block pedestrian crossings require a greater length of restricted curbside parking for adequate sight distance. Usually at least 30m (100ft) is necessary. It is recommended by the MUTCD that curbside parking be prohibited within 30m (100ft) before and 3.1m (20ft) after signalized mid-block crossings. (*37*)

Issues concerning on street parking in suburban and urban areas merit attention. Parking restrictions in rural areas are generally less of a concern because of the low numbers of pedestrians and parked vehicles.

Lighting

The New York City Department of Transportation Pedestrian Group commissioned a study of lighting effects on aesthetics, social and practical issues concerning pedestrian activity in 1995. The approach used did not separate the categories but evaluated overall effects. The following list is general guidelines identified for improving community lighting (*86*):

- Identify locations that show indications of revitalization and "grassroots activity" (For example: community gardens, murals, and play areas).
- Involve community member for the identification of appropriate sites through observations and interviews. Contact "key informant" (For example: local librarians, pastors, business owners, and community leaders) to discover which streets are used or avoided and why, to inform community members of the installation of street lighting, and to seek feedback for the proposed lighting designs and reactions after installation

- Recognize and highlight attractive and socially or historically significant structures. (For example: water towers, buildings with murals, churches, libraries, and any building that is particularly important due to location, history, or function.)
- Identify and light streets leading to and from facilities that accommodate community activities after dark, paying particular attention to potentially dangerous underpasses and alleys. (For example: streets connecting residential areas to places of community activity—public transportation terminals, churches, community centers, and stores.)
- Determine existing lighting elements that have been successful and could be applicable. Possible solutions may be:
    - encouraging family-oriented stores to remain open later
    - insisting new construction plans include lighting that will enhance the pedestrian environment
    - encouraging store owners to keep signs on all night
    - posting the city maintenance phone number to encourage prompt reporting of burnt-out lights
    - increasing efficiency of existing lighting by painting adjacent (horizontal and/or vertical) surfaces white
    - encouraging community facilities to provide additional light to highlight the entry, architecture, flags, and signs
    - continuing to operate festive streetlights at night year round
    - enforcing existing codes applicable to residential buildings
    - identifying areas that revitalization efforts will support or be supported by existing street activity

It is important to not target streets simply because they are dark. This practice could lead to providing lighting for streets that are not used or are unsafe. Pedestrians may believe lighting implies safety. Criminals in these areas are likely to break fixtures because they do not want to be seen.

Bus Bulbs

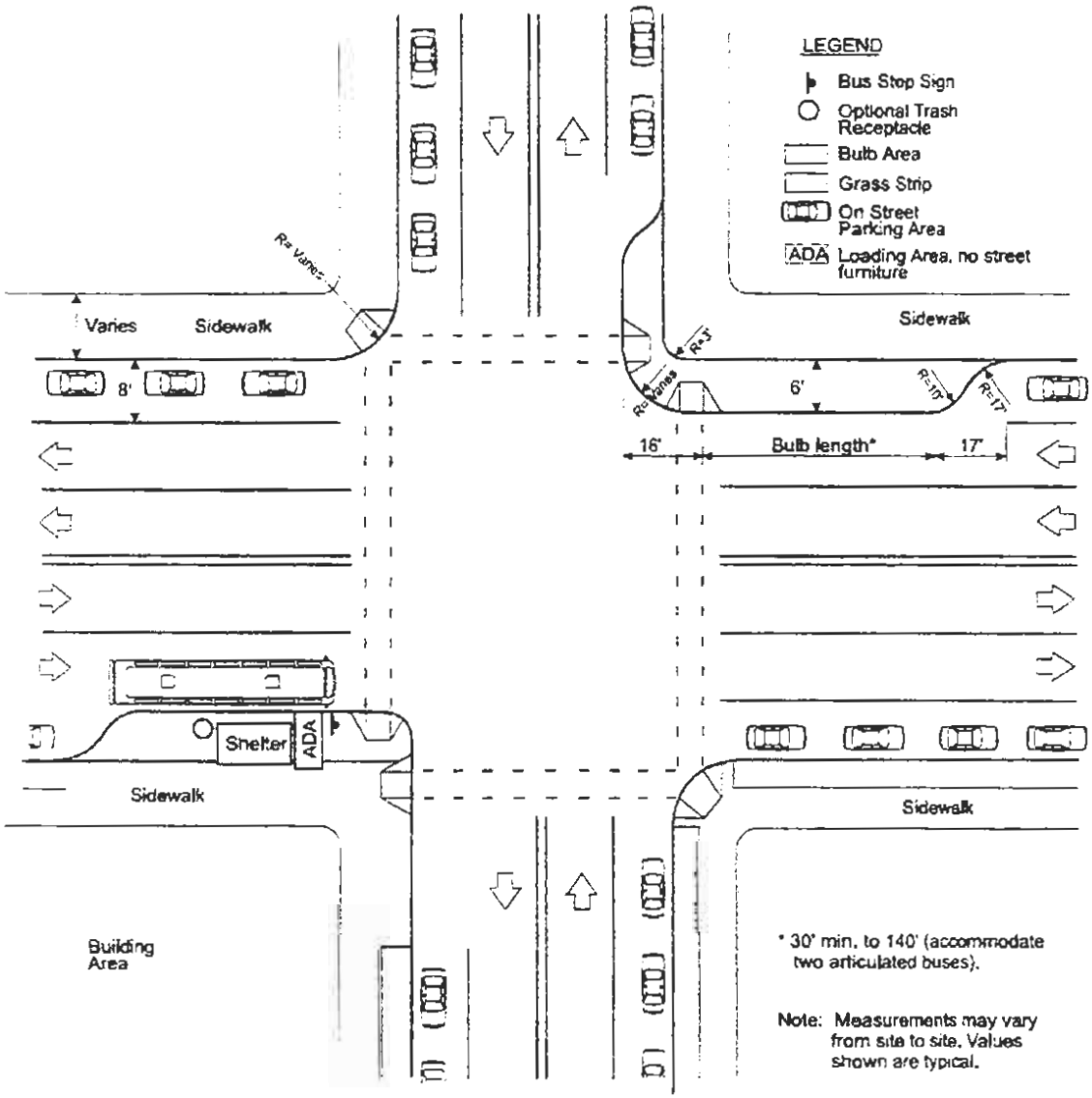
Bus bulbs are extensions of the curb through the parking lane to the edge of a through traffic lane at transit stop locations. Figure 3-15 depicts the geometric properties of an intersection with bus bulbs. Bus bulbs serve three main purposes (*89*):

1. Bulbs provide additional space for transit amenities such as shelters and benches;
2. Bulbs allow through pedestrian travel at congested stops; and
3. Bulbs eliminate the bus-weaving maneuver necessary to enter bays.

The 2001 "Evaluation of Bus Bulbs" studied the before and after effects of implementing a bus bulb at the intersection of Mission and 30th Street in San Francisco, California. The area of space per pedestrian was measured one minute prior to a bus arrival, during the interval the bus was present, and one minute after the bus departure. The available waiting area around the bus shelter increased 64% from 16.1m^2 (173 ft^2) to 26.4m^2 (284 ft^2).

There was an increase of both available area per pedestrian and LOS. The greatest distinction occurred during the period passengers board and alight.

Conflicting movements, streams, and walking speeds around the queuing area are potential pedestrian congestion problems. The available area space increased from 1.8 m^2/pedestrian (19 ft^2/pedestrian) to 4.1 m^2/pedestrian (44 ft^2/pedestrian). This improvement allows pedestrians to pass slower traffic easier, cross conflicting flows easier, and pass standing pedestrians easier. (*89*)



SOURCE: Evaluation of Bus Bulbs

Figure 3-15: Typical Bus Bulb Dimensions

After the bus bulb was constructed, almost 26% of all observations during the boarding and alighting were LOS A or B, while previously during the same conditions only 4% of observations were LOS B or above.

The average flow rates of pedestrians along the sidewalk improved by 11%, from 1.2m/ped/min (4 ft/ped/min) to 1.1m/ped/min (3.6 ft/ped/min). (*89*)

NEWSLETTERS/PUBLIC EDUCATION

Kill Your Speed

"Kill your speed" is the slogan for a pedestrian safety television campaign in the United Kingdom. The Department of the Environment, Transport and the Regions (DETR)- formerly Department of Transport in the United Kingdom- is responsible for the television shock ads that show actual video footage of child pedestrian victims. These messages stress driving at appropriate speeds and compliance with speed limits. (*65*)

Walk Smart Baltimore

Walk Smart Baltimore is a test program to use education, enforcement, and engineering to address the problem of collisions involving pedestrians who have used alcohol.

Data analysis of pedestrian collisions in Baltimore, Maryland has revealed that for the years of 1990-1992 over 40% of adult pedestrians (specified as age 14 and older) involved in collisions had been drinking. A study of the development, implementation, and evaluation of a program to address the problem of alcohol-involved pedestrian collisions is being performed in Baltimore by Dunlap and Associates, Inc. with the National Highway Traffic Safety Administration, USDOT. (*88*)

The countermeasures for this program include:

- Public Information and Education
    1. target group and community at large
    2. drivers
- Police Involvement
    1. training
    2. regular patrol of taverns
    3. vouchers for free rides home
- Server/Seller Responsibility
    1. high visibility grocery bags
    2. training
    3. service restrictions to intoxicated patrons
    4. high visibility patches for patrons
- Traffic Engineering in Problem Areas
    1. post "pedestrian crossing" signs at problem locations
    2. post warning signs "pedestrian injured/killed here" or "pedestrian safety—please cooperate"
    3. reduce speed limits
    4. provide cut-throughs in medians
    5. install stop signs
- Municipal/Community Groups
    1. specify problems in neighborhoods
    2. distribute background information
    3. provide training for municipal employees

4. locate and remove high blood alcohol content pedestrians from streets

- Hospital/Medical Community
    1. identify and treat those at risk
- Schools
    1. target problem youth
- Unassigned providers
    1. give away high visibility brand name clothing

Drink Safe Walk Safe

"Drink Safe Walk Safe," is a public campaign in South Sydney, Australia, with the intended purpose to educate about dangers of pedestrians under the influence. The program incorporates engineering, education, environment, and enforcement to help combat the problem of alcohol related pedestrian collisions. (South Sydney Packet) This program is similar to "Walk Smart Baltimore."

SUMMARY

Pedestrian travel can be a viable and enjoyable means of mobility for short distances. Many economic, health, and environmental benefits would be associated with an increase in trips made by walking. A relatively recent awareness and concern for the safety and accommodation of pedestrians has led to an enhanced pedestrian environment in many communities.

The U.S. government and the state of California have made the safe accommodation of pedestrians a priority. The USDOT has adopted a policy in which pedestrian accommodation must be established for "all new construction, and reconstruction projects in all urbanized areas," unless special circumstances exist. A national goal to double the number of pedestrian trips while reducing the number of pedestrian injuries and fatalities by ten percent has been established. A similar goal for California is to reduce the number of pedestrian collisions by twenty percent by the year 2018. *(23,24)*

Several well-developed pedestrian design guidance manuals exist. The primary emphasis of these manuals is the design elements of walkways, pedestrian crossings, traffic calming treatments, and accommodation of older and disabled pedestrians. Much importance is placed on meeting the ADA standards. Many treatments appear to have merit. However, a careful evaluation of potential safety benefits has not been completed for most of the treatments. In most cases, collision studies with statistically significant conclusions will not be possible. Use of most of the treatments is not widespread, and pedestrian collisions are (fortunately) rare events.

The pedestrian experience should be safe, accessible, and comfortable. Established treatments, such as marking crosswalks and providing pedestrian signal heads, are continually being reviewed for their effectiveness. Relatively new pedestrian elements, such as in-pavement crosswalk lighting and pedestrian signal countdown timers, are being implemented and studied further. Efforts should be made to perform careful safety evaluations of the treatments whenever practical.

4.0 COMPARATIVE ANALYSIS OF BEST PRACTICES

INTRODUCTION

After compiling relevant information from the extensive literature review, a comparison between Caltrans current practices and other agencies was conducted. In this chapter, various pedestrian policies are presented for possible implementation by Caltrans. These policies have also been evaluated qualitatively in order to make recommendations about how Caltrans should deal with each possibility. In the evaluation of each topic, the following three items were used:

- Recommendations were made with the focus of increasing pedestrian travel and decreasing pedestrian collisions.
- The information that was obtained from the literature search was used to help formulate recommendations.
- Statewide pedestrian collision data was utilized to determine trends in the types and causes of pedestrian collisions. This information from the collision data was used in formulating some generalized recommendations.

PEDESTRIAN COLLISION DATA ON STATE HIGHWAYS

Since there is a goal to reduce pedestrian collisions by 20%, recommendations should include strategies that target large numbers of pedestrian related collisions.

The following data was obtained from the Caltrans collision database that includes pedestrian and dismounted pedestrian collisions on state highways for the years of 1996 through 2000 (dismounted pedestrians consist of operators and passengers of disabled vehicles who have left their vehicle). The pedestrian collision data is divided into many different categories based upon the causes and circumstances of the collisions.

The following are the number of pedestrian related collisions described by the severity of the collision, persons injured, etc.:

- 8, 383 – Total pedestrian related collisions
- 1,177 – Fatal collisions
- 6,828 – Injury collisions
- 378 – Property damage only collisions
- 1,230 – Fatalities in all collisions
- 9, 272 – Persons injured in all collisions

As can be seen, almost all pedestrian collisions are severe, as shown by an injury or fatality occurring in over 95% of pedestrian collisions.

The percentages of pedestrian collisions characterized by access control are:

- 59.1% - Conventional highway
- 37.1% - Freeway
- 2.3% - Expressway
- 1.3% - One way city street

Thirty-seven percent of pedestrian collisions occurred on freeways, while 21.6% of pedestrian collisions involved dismounted pedestrians. This suggests that at least 14.5% of pedestrian collisions occurred on freeways involving pedestrians that were not dismounted. This is a significant number of pedestrian collisions that occur on roadways where pedestrians are not allowed.

The following are the percentages of pedestrian collisions characterized by the primary collision factor.

- 22.1% - Failure to yield
- 12.3% - Speeding
- 5.0% - Improper turn
- 4.5% - Influence of alcohol
- 47.6% - Other violations
- 8.2% - Other causes that are not traffic violations

As can be seen from the data, more than 90% of all pedestrian collisions involve a primary collision factor that is a "violation" of the Vehicle Code, with 4.5% of these collisions being alcohol related. Pedestrians are not required to know and study the vehicle code. Most citizens know that driving under the influence of alcohol can cause serious collisions. Most citizens don't see "failing to yield" as being as dangerous as driving under the influence, when in reality it is a factor in four times as many pedestrian collisions. To counteract this trend, public education should be utilized to help the public to see many other "violations," other than alcohol, are dangerous and result in injuries and fatalities.

The following are the percentages of pedestrian collisions characterized by roadway conditions as it relates to the vehicle involved in the collision.

- 1.3% - Obstruction on road
- 2.5% - Construction/repair zone
- 93.5% - No unusual condition
- 2.7% - Other roadway conditions

The roadway condition is not a substantial contributor to pedestrian collisions. As stated above, 93.5% of pedestrian collisions occurred when there was no unusual roadway condition.

Here are the percentages of pedestrian collisions characterized by lighting at the time of the collision.

- 52.1% - Daylight
- 26.8% - Dark with street light
- 17.0% - Dark with no street light
- 4.1% - Other lighting conditions

Illumination of streets may be important. It is likely that there would be substantially more pedestrians on roadways with street lights. The pedestrian collision rate may be higher on roadways with no street lights. This is a qualitative finding due to the lack of pedestrian travel data in lighted versus non-lighted areas.

Percentages of pedestrian collisions are characterized here by pedestrian type:

- 78.3% - Pedestrian
- 21.6% - Dismounted pedestrian

Dismounted pedestrians leave a vehicle along a highway and are involved in a collision.

The following are the percentages of pedestrian collisions characterized by the movement preceding the collision. These are characterized by both the vehicular movement and the pedestrian movement that precedes the collision. Please note that the vehicular percentage sums to over 100% due to some collisions being classified as having more than one movement before the collision.

- Vehicular movement:
  - 63.7% - Proceeded straight
  - 10.0% - Stopped
  - 12.6% - Making right turn
  - 8.8% - Making left turn
  - 8.4% - Parked
- Pedestrian movement:
  - 32.6% - Crossing in crosswalk at an intersection
  - 1.5% - Crossing in crosswalk at a non-intersection
  - 24.2% - Crossing without a crosswalk
  - 35.1% - Traveling on roadway (including shoulder)
  - 6.6% - Other pedestrian movements

As seen from the above data, more crossing pedestrian collisions occur in crosswalks than outside crosswalks, and 35.1% involve pedestrians within the roadway or the shoulder.

PLANNING

Methods of Estimating Pedestrian Demand

The 1999 *Guidebook on Methods to Estimated Non-Motorized Travel: Overview of Methods* (*26*), compiled eleven methods used in non-motorized demand estimation, relative demand potential, supply quality analysis, and supporting tools and techniques. Examples of applications, advantages, disadvantages, and ratings of each method are discussed.

Recommendation: It is recommended that the development of pedestrian travel estimation methods be considered to be included in developing state routes in urban areas without access control. It is also recommended that the same estimation methods be used in areas with high pedestrian populations due to recreational activities. In the development of this evaluation method, it is recommended that Caltrans classify the pedestrian demand that is associated with highway projects as "low," "medium," or "high." It may be necessary to complete a Level of Service

analysis for the projects that are classified as having "high" pedestrian demand. Some qualitative guidelines need to be established to assist in identification of "low" and "medium" pedestrian demand.

Capacity and Level of Service

Research at North Carolina State University pertaining to non-motorized capacity and level of service has led to a three part report recommending changes and additions to the Highway Capacity Manual. The report is titled: *Capacity Analysis of Pedestrian and Bicycle Facilities: Recommended Procedures for the "Pedestrians" Chapter of the Highway Capacity Manual, Recommended Procedures for the "Bicycles" Chapter of the Highway Capacity Manual, and Recommended Procedures for the "Signalized Intersection" Chapter of the Highway Capacity Manual. (29)*

The recommendations included in the report are to alter existing procedures and incorporate additional procedures to the Highway Capacity Manual on topics such as:

- Pedestrian Model Dimensions (for Design Purposes)
- Walking Speeds
- Capacity thresholds
- Level of Service
- Pedestrian Delays at Crossings

Recommendation: Research in this area will undoubtedly continue and should be reviewed for specific applicability. These topics are specifically important and should be considered for state routes without access control. Caltrans should take an active role with the on-going HCM efforts regarding pedestrian level of service analysis methodology.

Locations that are identified as having an estimated "high" pedestrian demand will require careful analysis. The analysis will determine, through application of capacity and level of service computations, if space allocated to pedestrian travel (i.e. sidewalks) should exceed minimum standards.

WALKWAYS

Sidewalks

Rating System of Sidewalk Conditions

The Adirondack/Glens Falls Transportation Council uses a rating system, which is described in the *Glens Falls Sidewalk Evaluation and Rating Manual*. This system assesses the necessity of repairs or replacements of the area sidewalks by a numerical rating evaluation. Four factors are used in this evaluation—physical condition, street functional classification, proximity to pedestrian generators, and ADA compliance. Each category is scored and entered into a spreadsheet program.

By using consistent appraisals, the sidewalks in the most need of attention will be able to receive a portion of the limited funds appropriated for repair and replacement (*40*).

Recommendation: It is recommended that Caltrans develop a rating system and inspection plan for sidewalk maintenance. A legal precedent has been set by

California that involves unsafe conditions of public property. This precedent involves the maximum abrupt elevation change that can exist on the sidewalk surface for the sidewalk to be considered safe. This precedent should be considered in the development of the sidewalk rating system. Sidewalks adjacent to state highways are often under the jurisdiction of local agencies, so cooperation between Caltrans and local agencies may be necessary for the development of the rating system.

Locations for the Installation of Sidewalks

Under current standards in the Highway Design Manual (HDM), the State "may assume financial responsibility for the construction of sidewalks," when at least one of the 11 listed conditions is met in Section 105.1 of the HDM apply. This standard does not seem to satisfy the policy statement of the US DOT (*Design Guidance—Accommodating Bicycle and Pedestrian Travel A Recommended Approach*) on incorporating non-motorized transportation facilities into all transportation facilities unless "exceptional circumstances exist".

Recommendation: Caltrans should review The US DOT policy statement and modifications to the Highway Design Manual should be made as appropriate.

Obstacles

There are many possible obstructions that need to be considered, including light poles, traffic signs, benches, mailboxes, and trees. Drain grates, manhole covers, and other utility coverings should be located out of the pedestrian traveled way whenever possible. If it is unavoidable to place these obstructions elsewhere, the ADAAG requires that covers be flush with the surface and no opening may be larger than 1.3cm (0.5in). The ADAAG also requires specific specifications for objects protruding from walls.

Recommendation: Cost should be given consideration when investigating the feasibility of removing obstacles from the pedestrian pathway. The obstacles should be removed when reconstruction occurs, if possible. A program to remove obstacles in "high" pedestrian demand areas need be established.

Buffers

Buffers, also referred to as planting strips, landscaped strips, or setbacks, should be incorporated into all sidewalk sections when feasible.

The absence of buffers can the pedestrian's sense of security. Vertical curbs are recommended for added protection when buffers are not present.

A setback of over five feet between the curb and sidewalk is recommended. This increases pedestrian safety and reduces splashes from passing vehicles in wet weather.

Recommendation: According to the *Pedestrian Facility Guidelines* published by the Missouri Department of Transportation, sidewalks may not be located directly adjacent to travel lanes where the design speed is 70 km/h (45mph) or the posted speed is greater than 65km/h (40mph). These design criteria apply specifically to all higher speed state highway routes. It is recommended that the California Highway Design Manual adopt similar guidelines regarding sidewalks provided right-of-way is available. (The HDM already deals with curbs.)

Design Standards

Little guidance exists pertaining to sidewalk geometric design within the Caltrans manuals. The only guidance that is provided involves driveways and curb ramps at intersections. Meeting the ADA requirements will control many of the design parameters such as cross-slopes, grades, and minimum clear widths. In areas of heavy pedestrian traffic, standards should be developed for comfortable accommodation of pedestrians based on level of service analysis. Caltrans is currently addressing ADA requirements through a design bulletin. (*18*)

Recommendation: It is recommended that Caltrans follow through with integrating the ADA requirements. Also, level of service analysis should incorporate the idea of pedestrian comfort. Geometric sidewalk design standards should be established and compiled.

Pedestrian Use of Shoulders

Widening a state highway shoulder to improve safety and convenience for non-motorized users is listed as an example of a project that qualifies for state funding in chapter 31 of the Project Development Procedures Manual. However, no mention of the use of shoulders by non-motorized traffic is included in the sections pertaining to shoulders in the HDM. Topic 1003 of the HDM states that the shoulder width should be a factor when considering the allowance of bicycle travel on freeways.

The definition of shoulders in section 62.1 of the HDM is, "The portion of the roadway contiguous with the traveled way for accommodations of stopped vehicles, for emergency use, and for lateral support of base and surface courses." The AASHTO publication, *A Policy on Geometric Design of Highways and Streets* (*43*) states that shoulders are desirable on all highways and urban arterials. In addition to structural benefits, shoulders accommodate the following:

- Recovery area for errant vehicles.
- Pedestrian travel.
- Bicycle travel.
- Disabled vehicle refuge.
- Snow storage (for plowing operations).
- Bypass space for through-traffic passing left turning vehicles.

The USDOT, with contributions from public agencies, professional associations, and advocacy groups, issued a policy statement regarding the goal of integration of walking and bicycling into the transportation infrastructure. There are four parts to the policy statement issued. One of the four portions states paved shoulders should be included on rural roadways used by more than 1000 vehicles per day to provide accommodation for pedestrians and bicyclists.

Opinions differed in the literature regarding the appropriateness of using shoulders to accommodate pedestrians. While the 1998 *Statewide Bicycle and Pedestrian Master Plan* from Louisiana states, " For the pedestrian, a paved shoulder can offer a safe route away from the path of motorists along an otherwise hazardous road," the 1998 ITE *Design and Safety of Pedestrian Facilities* states, "In extreme cases, a roadway shoulder can also provide a safer pedestrian accommodation than walking in the travel lanes themselves."

Recommendation: In the literature researched there was agreement in the philosophy that sidewalks and walkways are preferred to shoulders for pedestrian travel (pedestrians should not be encouraged to travel upon highway shoulders, especially on high-speed or high-volume highways). Where pedestrian demand is "medium" to "high" separate paths or sidewalks are recommended. In other areas a minimum shoulder width of 8' (2.4 m) should be followed.

AT-GRADE CROSSINGS

Alternative Markings for Crosswalks ("High Visibility Crosswalks")

The Caltrans Traffic Manual (1996) section 6-02.12 states the markings used to designate a crosswalk are two solid lines establishing the edges. When crosswalks markings are used, their line widths should be no less than 300 mm (12 in) and the marking should be a solid white line except at school crossings which are yellow. Diagonal or longitudinal lines are also acceptable within the crosswalk. These diagonal or longitudinal lines should be 300-600mm (12-24in) in width and be spaced 300-600mm (12-24in) apart. The transverse markings establishing the crosswalk edges may be omitted except in the case of a crosswalk that is marked for the purpose of clarifying a pedestrian route for the visually impaired.

The pedestrian literature review documented several types of high visibility crosswalks in use. These are the zebra crossing, ladder crossing, piano crossing, and the solid markings. A dashed European style is also sometimes used and captures attention because it is unfamiliar.

A side benefit of the zebra, ladder, and piano style pavement markings is that they require less maintenance than that of the tradition parallel line markings. However, initially they are more costly because it takes more time to place these pavement markings. Subsequently, maintenance workers are exposed to traffic longer which increases safety concerns. This reduction in maintenance is attributed to tires driving over a smaller area of the markings. However, the alignment must be deliberately planned to minimize the wear due to tires. (*37*)

Currently there is significant debate whether high visibility crosswalks should be reserved for locations with heavy pedestrian traffic. This would help ensure that overuse does not make the markings less effective. Another point of view is that consistency in markings should be maintained. Oregon DOT recommends the zebra crossing for added visibility and effectiveness without a discussion concerning overuse.

The 1998 *ITE Design and Safety of Pedestrian Facilities* (*32*) suggests the use of high visibility markings at locations where pedestrians may not be expected to cross, cross in high volumes, or when motorists may benefit from the added information. It is further stated that such markings should not be used in locations where other traffic control devices exist or to designate all marked crosswalks. The idea that indiscriminate use can reduce the overall effectiveness is cited.

A recent FHWA laboratory experiment found that a ladder design with a 0.3m (12in) stripe and 0.6m (24in) space was the optimal crosswalk pattern due to combination of cost considerations and laboratory visibility results. However, there

have been no conclusive accident studies and some agencies do not install high visibility crosswalk markings at any location.

An additional concern is that high visibility crosswalks will increase the pedestrian's feeling of safety and may cause less cautious crossing behavior. (*32*)

Salt Lake City, Utah has begun using an alternate version of the ladder crosswalk. It is called the double ladder crosswalk. It is identical to the traditional ladder version except for the exclusion of the middle third of the striping. In wet and icy weather the crosswalk markings can become slippery for the pedestrians. The double ladder crosswalk, while it has been found to be the same visually to motorists up to 45.7m (150ft), an unmarked, less slick section is created for the pedestrians' travel path. (ITE Journal February 1996)

Recommendation: It may be appropriate to address additional alternate types of crosswalk markings. Applicable issues would include: specifications, warrants, and consistency versus overuse.

Due to the drivers' difficulty in seeing crosswalk markings from farther distances, alternative markings should be considered when the drivers need additional visual reinforcement regarding the presence of a marked crosswalk. These alternative markings are not recommended at signalized intersections because motorists expect crosswalks in those locations. It is recommended to use only a limited number of alternative crosswalk marking styles. These alternative markings should be used sparingly so motorists do not become so accustom to the new style or crosswalk pavement marking, that they would go unnoticed by the motorist. Another recommended practice would be to illuminate all mid-block crossings so pedestrians will be more visible to motorists in nighttime conditions.

Pedestrian User Friendly Intelligent Crossings

Pedestrian User Friendly Intelligent crossings (PUFFINs) recognize, by infrared or microwave sensors, when pedestrians are lingering in the crosswalk. While sensors detect pedestrians in the crosswalk, the traffic signal is prohibited from changing to a green phase for conflicting traffic. These have been used for pedestrian crossings that typically accommodate slower pedestrian traffic such as in proximity to hospitals, retirement homes, and schools. (Canada and United Kingdom)

Recommendation: The 2000 MUTCD allows for the optional use of passive pedestrian detection equipment to avoid using a slower walking speed to determine the pedestrian clearance time. This device would need further study and evaluation before any recommendations for implementation should be made.

In-Pavement Crosswalk Lighting

An Intelligent Transportation System (ITS) used for pedestrian crossings is the flashing in-pavement crosswalk lighting. It is designed for use at unsignalized pedestrian crossing locations. The system has been found to increase the percentage of drivers who yield to pedestrians and the number of pedestrian/vehicle conflicts have decreased at these locations. Both pedestrian push button activation and automated detection have been used. The system is specifically recommended to be used when the pedestrian traffic is greater than 100 pedestrians per day. (*60*)

Recommendation: The in-pavement system in an option to be considered for use at mid-block crosswalks.

Supplementary Pedestrian Crossing Channelization Device

Warning Signs within Crosswalk—New York State Department of Transportation has developed specifications for a new Supplementary Pedestrian Crossing Channelization Device that can be placed within crosswalks. The device is constructed with traffic cone rubber and is fitted with a safety orange retro-reflective fabric jacket displaying the state law message "YIELD TO (PEDESTRIAN WALKING MAN SYMBOL) IN YOUR HALF OF ROAD." It is only intended for use at unsignalized, marked crosswalks where the speed limit is not greater than 48.3kmph (30mph) which Is rare on Caltrans state routes. It should be used in addition to standard pedestrian warning signs and pavement markings. The cost of each device is $125. (*66*) WSDOT documents that a similar device is being used in New Jersey that reads "STOP FOR PEDESTRIAN IN CROSSWALK." New Jersey had a previous hard material version that was banned due to the concern of creating projectiles if hit by a vehicle. These devices have been found to increase pedestrian safety, but concerns of vandalism and deliberate damage have become a problem. Also, the logistics and cost of manual placement and removal each day are additional concerns. (*60*)

Recommendation: This device is not recommended for state routes because of the disadvantages previously stated.

LED Animated Scanning Eyes Prompt Drivers To Look For Pedestrians

The 1999 *Canadian Research on Pedestrian Safety* suggests that the use of Light Emitting Diode (LED) animated scanning eyes may be more effective than the flashing beacon as a pedestrian warning device. These are lighted eyes displayed on a black background appearing to scan side to side. It is intended that when drivers see the scanning eyes they will be alerted to scan and look for pedestrians. It is speculated that the scanning eyes would be as conspicuous as a flashing beacon but would naturally prompt drivers to search for pedestrians. (*57*)

Recommendation: Alternative devices other than the "scanning eyes" appear to be more applicable for use on state routes. If the device were to be used, more research would be necessary preceding the implementation of the device as there is no documented evidence that suggests this tool improves pedestrian safety.

Internally Illuminated Crosswalk Warning Signs Posted Above Crosswalks

A study of several unsignalized intersections in Clearwater, Florida, found that internally-illuminated overhead crosswalk signs accompanied by high visibility crosswalks increased the percentage of drivers yielding to pedestrians by 30-40% during the day and by 8% at night. The number of pedestrians who looked before entering the crosswalk, forced the right-of-way, and ran across the road was not affected. The incidence of pedestrian/vehicle conflicts remained unchanged. (*60*)

Toronto, Ontario, has hundreds of internally illuminated overhead crossings signs with push button activated flashing beacons. Studies have found a decrease in pedestrian fatalities with this treatment. When these beacons are accompanied by a

pedestrian (symbol) crossing sign and a message, "STOP WHEN FLASHING" the number of motorists yielding increased. (*60*)

Recommendation: It is recommended that demonstration installations be tested at sites where there is a problem with pedestrian collisions. If it is determined that such an installation would be beneficial, a statewide standard for installation could be developed from information at the demonstration sites. The request for using this device would follow the standard procedures required by the California Traffic Control Devises Committee (CTCDC).

Push Button Actuated Fiber Optic Regulatory Sign Placed Above Crosswalks Stating, "Stop For Pedestrians In Crosswalk"

The city of Tucson, Arizona, has implemented an overhanging regulatory fiber optic sign stating, "STOP FOR PEDESTRIANS IN CROSSWALK" that is activated immediately by a pedestrian push button. The flashing phase was typically set to accommodate a walking speed of 1.2m/s (4ft/s) plus a constant of 5 seconds. The fiber optic signs have been installed on multilane highways at locations where vehicles have a history of not yielding to pedestrians and the vehicular speed is less than or equal to 64kph (40mph). A study by Huang and Zeeger found that this did not increase the numbers of motorists who yielded to pedestrians. City traffic engineers were prompted to work with local police for enforcement. Huang and Zeeger suggest that this type of regulatory sign may be more effective on two lane roads with speed limits between 48 and 56kph (30 and 35mph).

Recommendation: These have similarities to devices described in the previous section. Evaluations cited do not appear to show great effectiveness. Trial installations are not recommended at this time.

Passive Pedestrian Detection At Unsignalized Crossings

The Caltrans Traffic Manual (1996) section 3-03.25 "Pedestrian Detectors" discusses only the push button type of detector.

It has been shown that motorists become accustomed to pedestrian warning devices, such as flashing beacons or reflective warning signs, if always active. An alternative is to provide warning devices that are only active when a pedestrian is present. However, observations reveal that some pedestrians fail to press the button at unsignalized crossings to initiate such a warning device.

Five forms of passive pedestrian detection, namely passive infrared, ultrasonic, Doppler radar, video imaging, and piezometric were studied. Passive infrared and Doppler radar were described as promising by authors Beckwith and Hunter-Zaworski. (TRB No.1636 "Passive Pedestrian Detection at Unsignalized Crossings.") Based on comparisons of the various types of detection, the piezometric detection method is the most effective detection method.

Recommendation: It is recommended that a few demonstration installations be implemented and analyzed. The request for using this device would follow the standard procedures required by the CTCDC for experimental use.

Walking Speeds Used To Time Signalized Pedestrian Crossings

Caltrans Traffic Manual (1996) section 9-04.7 Pedestrian Detectors states, "The total pedestrian crossing time shall consist of the walk interval plus the pedestrian clearance time obtained by using a walking rate of 1.2 m/s (3.9 ft/s). Under normal conditions, the walk interval should be at least 4 seconds in length." (*26*)

Alternate sources such as the *Portland Pedestrian Design Guide* state that 3.5 ft/s is more appropriate to accommodate older pedestrians. The 2000 MUTCD states, "Where pedestrians who walk slower than normal, or pedestrians who use wheelchairs, routinely use the crosswalk, a walking speed of less than 1.2 m (4 ft) per second should be considered in determining the pedestrian clearance time."

A study of walking speeds in crosswalks by Knoblauch, Pietrucha, and Nitzburg found that the 15th percentile of older pedestrians (specified as 65 and older) was 0.97 m/s (3.19 ft/s). The conclusion to this study was that a design speed of 0.9 m/s (3.0 ft/s) was appropriate for older pedestrians. (*67*)

The 1999 *Designing Sidewalks and Trails for Access—Review of Existing Guidelines and Practices* (Publication No.: FHWA-HEP-99-006) states that the use of a 0.85m/s (2.8ft/s) walking rate may be more appropriate for the accommodation of older pedestrians. It is important to note that walking rates depend on many factors. Rates are faster at mid-block crossings for men as opposed to women. Walking speeds also vary depending on purpose of trip, climatic conditions, steepness of grades, and time of day. (*52*)

Recommendation: It is appropriate to review the pedestrian crossing speed standard established in the Traffic Manual. To evaluate the need for decreasing the walking speeds at specific intersections, it will be necessary to assess the nature of pedestrian demand at the intersection. This assessment should determine the walking speeds of the pedestrians and the percentage of slower moving pedestrians that used the crossing facilities. The Traffic Manual should allow for walking speed as low as 0.9m/s (3ft/s) where conditions warrant. If it can be shown that individual locations must be assessed to determine walking speed, then it is recommended that the Traffic Manual be revised to reflect this individualized attention at each location.

Illuminating Pedestrian Call Push Buttons

The most common pedestrian detection device is of the push button type. Often the "WALK" interval follows in a few seconds after the push button is activated, but in many locations the "WALK" interval will accompany the appropriate green traffic signal phase and the delay for pedestrians can be a minute or more. Pedestrians can become discouraged with the belief that the call button is inoperative and cross against the signal. The Portland Pedestrian Design Guide states that a push button that lights upon activation (such as an elevator button) may be helpful in this situation. The life of the push button actuator may also be increased because pedestrians could observe that a call had been received, resulting in less use.

Recommendation: These illumination devices should be used only if it is determined that there is a pedestrian confusion with the existing push button devices or with pedestrians crossing against signal lights thinking the push buttons do not work.

Countdown Timers Included On Pedestrian Signal Heads

Countdown timers have been included on the traditional style pedestrian signals. There are two types of countdown timers used to aid pedestrians. One shows the time remaining until the next walk indication. It is thought that this type of countdown timer would encourage pedestrians to wait for their crossing phase because a definite amount of waiting time has been established to the pedestrian. The other type of count down timer counts down the pedestrian walk phase. Time remaining to cross the street without vehicular conflicts is shown. Both may be used at one location. It is believed that the extra information could aid the pedestrian in their crossing maneuver, enabling individuals to assess their ability to finish crossing within the allowable time.

Recommendation: These devices would be appropriate and potentially effective where large pedestrian traffic volumes occur.

Pedestrian Scramble

The City of San Francisco Department of Parking and Traffic reports the use of the pedestrian scramble crossing phase. All vehicular traffic is stopped in all directions and pedestrians may cross in any direction including diagonally. It has been found to be most effective in areas of very high pedestrian traffic volumes. Vehicle delay in this situation could have a negative impact on the overall operations of the intersection depending on the traffic volumes in the area. The use of the Pedestrian Scramble System could be used to reduce pedestrian versus turning vehicle collisions. (*68*)

Recommendation: Pedestrian scramble could be appropriate for state routes where the roadway is narrow and in an urban area. When crossing wide streets, pedestrians often need a refuge island, which would not be available in the center of the intersection for those pedestrians that choose to cross diagonally.

Encouragement to Search for Turning Vehicles at Signalized Intersections

In a Canadian study, the words, " WATCH FOR TURNING VEHICLES" were posted on a sign and/or painted within the crosswalk. It was observed that this treatment increased the percentage of pedestrians who looked for turning vehicles.

An auditory message stating, "Please wait for WALK signal," is played when the pedestrian push-button is depressed. A second message stating, "Look for turning vehicles when crossing [street name]," is played 0.2 seconds before the pedestrian signal head displays the walk symbol. This treatment increased the percentage of pedestrians searching for turning vehicles. A childlike voice was found to be more effective than a woman's voice.

An experiment is planned in Florida to add a set of lighted eyes to pedestrian signal heads. The pupils of the eyes will accompany the steady walk symbol appearing to scan back and forth 2 times per second for the first two seconds of the walk phase. The remaining steady walk symbol will not include the scanning eyes.

Recommendation: Statewide collision data suggests that there may be a problem with pedestrian collisions involving turning vehicles. Auditory messages

may be effective when there is high pedestrian volumes, high turning vehicle volumes, or a history of pedestrian versus turning vehicle collisions.

Accessible Pedestrian Signals

The American Council of the Blind defined an accessible pedestrian signal as follows: "Accessible pedestrian signals provide information in non-visual format, which includes audible tones or verbal messages, and/or vibro-tactile information." (*80*) Accessible pedestrian signals have diverse characteristics.

In addition to aiding those with visual deficiencies, there is some evidence that audible signals may reduce pedestrian conflicts overall. Pedestrians with cognitive deficiencies may also benefit.

In *Accessible Pedestrian Signals*, eleven specific products on the market are described by the following nine characteristics: (*83*)

- Type of device: speaker mounted in pedestrian signal head, transmitter mounted in pedestrian signal head, or push button integrated.
- Audible sound: voice, bell, buzzer, birdcalls, ticker, or tones.
- Volume: fixed, variable by the installer, automatically varies according to surrounding sound level, variable by user, or audible only at user request.
- Presence of locator tone to direct user towards pushbutton.
- Presence of special tone indicating beginning of walk interval.
- Presence of vibrating sidewalk.
- Actuation feedback: light or tone indicating pedestrian call has been registered.
- Tactile element ("textured" sidewalk surface): arrow indicating the direction a push button is functional or tactile information about intersection geometry.
- Street name information.

In some countries all newly installed pedestrian signals must be of the audible type. In the U.S. individual requests must be made along a specific route for the installation. (*84*)

The City of San Francisco has installed infrared transmitters called "talking signs" at several intersection locations to transmit audible messages to visually impaired pedestrians equipped with hand-held receivers. The audible message identifies the location, travel direction and the name of the street to be crossed, in addition to real time information about the pedestrian signal indication (*68*)

Augusta, Georgia, has installed two audible pedestrian signals near a VA Hospital with a visually impaired rehabilitation center. A locator tone directs the visually impaired pedestrian towards the signal button. Braille instructions are located on the front of the signal. A chirping noise confirms that the call message has been received. The locator tone resumes until the crossing phase begins. At that time a voice states, "Walk light on to cross Wrightsboro Road." A different tone indicates

the flashing "DON'T WALK" indication. This location is also equipped with a vibrating indication, which varies the frequency of the vibration according to the crossing phase to aid pedestrians who are both visually and hearing impaired. (*85*)

Recommendation: Audible devices should be installed whenever there is an observed demand or a request for their presence. The device used by San Fransisco, California, appears promising.

Pedestrian Signal Head Warrants

At signalized intersections, Sacramento County assumes pedestrian signal heads and activation will be needed at all sites rather than using warrants. Additionally, audible sounds to direct visually impaired pedestrians are standard at all signal systems as well. It is believed that applying warrants will discourage pedestrian traffic until pedestrian devices are installed.

Recommendation: To encourage pedestrian travel, Caltrans should apply this policy in urban and suburban areas. As a minimum, all traffic signal systems should be designed and constructed such that pedestrian signal heads and pedestrian detector devices can be added when needed (i.e. the wiring is already in the traffic signal system).

Roundabouts

More research is necessary regarding pedestrian safety at roundabouts. A standard location for the placement of crosswalks has not been established. Pedestrians are unlikely to travel too far out of their way to use a crosswalk. However, if the crossing is located close to the circular intersection the flow of the traffic could be negatively affected within that circular intersection.

Accommodating visually impaired pedestrians at roundabouts is a concern. Roundabouts allow the uncontrolled exit of the circular intersection and a pedestrian crossing signal at each of the legs will obstruct the exiting flow, contradicting the intended purpose. Audible cues typically used by visually impaired pedestrians while crossing can be confusing at a roundabout due to the circular geometry.

Additionally, by the definition of a crosswalk, unmarked crosswalks cannot exist at roundabouts. More research is required on the effectiveness of high visibility crosswalks at roundabouts.

Recommendation: The following are observations and recommendations concerning roundabouts:

- If roundabouts were to be used with high pedestrian and vehicular travel, grade separated pedestrian crossings are recommended as the preferred method of handling pedestrian travel.
- Pedestrian signals are not recommended for use with roundabouts.
- If the traffic volumes are low, pedestrians could safely cross at (or near) a roundabout, except when high volumes of visually impaired pedestrians are present.
- Pedestrian crossings should not be located close to the entrance to the roundabout because, as motorists approach the roundabout, their attention

is focused on merging into the roundabout. Consequently, the motorist is more likely to miss observing the presence of a pedestrian in the crosswalk.

- Formal research and study about pedestrians at roundabouts should be conducted in an effort to better study how the two can be made more compatible.

Railroad Crossings

Trains possess the right of way at railroad crossings. To increase pedestrian safety at railroad crossing locations two alternatives are possible. The first is to stop pedestrians from entering the track area while trains are approaching or passing, and the second is to provide a grade separated crossing facility.

Grade separated crossing structures are expensive and are appropriate only under heavy pedestrian traffic conditions. Railroad crossings that are located on school routes are good candidates for a grade separated pedestrian crossing. A crossing guard should be considered as an alternative in school routes. A warrant analysis should be conducted. (*31*)

When pedestrians cross railroad tracks, the surface should be smooth. Timber, asphalt, rubberized material, and concrete surfaces are all used at crossings. Concrete is recommended due to the smoothness created and durability of the material. Timber tends to wear down and is slippery when wet. Maintenance must be periodically performed on asphalt to prevent bulging next to the rails. (*31*)

The ADA requires a maximum elevation difference at pavement joints or between adjacent surfaces of 1.3 cm (0.5 in). Pedestrian crossings should form an approximate right angle with the railroad tracks. Signs and pavement markings are required to warn pedestrian, bicyclists, and vehicle operators of upcoming railroad crossings. (*31*)

Recommendation: It is recommended that highway crossings be at a right angle to the railroad tracks. This perpendicular geometry will help prevent wheel chair or bicycle tires from getting caught in the groove that occurs between the track and the adjacent asphalt. This detail of railroad crossings and the ADA requirements should be incorporated into the Highway Design Manual for new construction. Maintenance activities should be sufficiently frequent so as to maintain adequate smoothness.

GRADE-SEPARATED PEDESTRIAN CROSSINGS

The geometrics of the roadway may dictate which type of structure -an overpass or underpass- is more feasible. In locations where a roadway is sunken, an overpass may not need a large elevation change to meet the vertical clearance requirements and would be the natural choice. While at other locations a raised roadway would facilitate an under-crossing more easily and economically.

Overpass

Overpasses are more common because of concerns regarding under-crossings relating to crime, vandalism, drainage, high water tables, relocation of utilities, and higher construction costs. Overpasses have a greater vertical clearance requirement and when spanning US Interstate Highways, they must meet military guidelines for vertical clearances. The height of these structures can require lengthy ramps in compliance with ADA standard and may demand extended right-of-ways.

Overpasses are easier to maintain and supervise. Fencing should be provided to prevent objects from being thrown off the structure into the roadway. At night the facility should be well lit.

Caltrans Highway Manual (1995) Section 105.2 states that where a pedestrian grade separated structure is justified an overpass is preferred due to the potential of crime and vandalism. Under-crossings can be considered when a local agency specifically requests, in writing, that an under-crossing be used. A clear view through the tunnel should be provided.

Underpass

Underpasses are sometimes needed to connect the pedestrian route to an underground parking garage or shopping center or in places where an elevated roadway exists. The perception that under-crossings are unsafe due to crime should also be considered. Underpasses should always be well lit and clear of debris and graffiti.

In the City of San Diego all the existing tunnels, four in total, have been taken out of service because of problems including crime, public nuisance, and general negative public reaction. No others are anticipated. (Comprehensive Pedestrian Crossing Policy—City of San Diego Council Policy April 1990 (Policy No. 200-07) All grade separated pedestrian crossing structures in San Diego are over-crossings.

Recommendation: Over-crossings are preferred to under-crossings due to concerns related to crime, vandalism, drainage, high water tables, relocation of utilities, and higher construction costs. No changes are needed to the Highway Design Manual.

Specific Warrants For Pedestrian Grade Separated Structures

Caltrans Highway Design Manual (1995) section 105.2 states that the need for a pedestrian grade separated structure should be based on a study of present and future conditions. These conditions include: pedestrian generating sources in the area, pedestrian crossing volumes, type of highway to be crossed, location of adjacent crossing facilities, circuity, zoning, land use, sociological and cultural factors, and age of persons expected to utilize the facility. Pedestrian patterns should be maintained across freeway routes where these patterns have been previously established. Where vehicular crossings are inadequate for pedestrians, separate structures should be provided. In general, if a circuitous route is involved, a pedestrian separation may be justified even though the number of pedestrians is small. Special consideration should be given to school crossings.

Other literature reviewed pertaining to pedestrian grade separations states that they have typically been located around universities, industrial plants, government

buildings, major shopping centers, large hospitals, recreation facilities and other major pedestrian generators. (City of San Diego)

Specific warrants were documented for pedestrian grade-separated crossings by E. A. Axler in the 1984 report *Warrants for Pedestrian Over and Underpasses*. A table appearing in the 1996 *Pedestrian Compatible Planning and Design Guidelines* (*38*) summarizes the volume warrants recommended by Axler.

The City of San Diego has its own criteria to warrant a pedestrian grade separated structures at both unsignalized and signalized intersections. In addition to the minimum warrants for the unsignalized intersection, an economic analysis must indicate that a pedestrian over-crossing will be less expensive than a traffic signal for a ten-year period.

Recommendation: When considering grade-separated structures, the presence of pedestrians should take into account the higher severity (7 to 17 times) of pedestrian collisions.

SCHOOL RELATED

Mandatory Annual Training And Certification For Crossing Guards In Florida

Florida Statute, Section 234.302 requires that counties with a population of 75,000 or greater, train and certify crossing guards. Crossing guard trainers must complete a twelve-hour course, which covers issues of pedestrian safety.

The crossing guard trainer is then qualified to conduct crossing guard training which consists of four hours of classroom training, two hours in-the-field-training, and two hours onsite observation, which is mandatory for certification. There is no cost to the individual for the training. (*37*)

School Safety Patrol Guidelines

A program to increase and encourage student pedestrian safety is the school safety patrol. Patrol members consist of individuals from the student body. The members should be selected from the upper grades (below fifth grade is not recommended) and possess leadership skills and reliability. Patrol membership is voluntary and open to all who meet the qualifications. The individual schools administer each program with the policies determined by the principal. (*Florida Pedestrian Planning and Design Handbook*, Florida Department of Transportation)

In-Pavement Centerline School Zone Lighting

An in-pavement lighting system has been developed for school zones. The flashing light fixtures are installed down the centerline of the roadway in school zones. An amber light is emitted and aimed towards the two directions of traffic. The flashing lights are set by timer to flash for one hour before the start of school and for one hour after school when children will be present. Typical installation is for fixtures to be located between 10.7-15.2m (35-50ft) apart. The lights can be seen at a range of more than 183m (600ft). (*79*)

Recommendation: These school safety programs and devices (crossing guards, safety patrol, and in-pavement lighting) are more likely to be local matters. However, Caltrans should certainly coordinate and cooperate with local and law enforcement agencies.

Relocate School Intersection Crossings to Mid-block Locations

One report from the Portland, Oregon, Bureau of Traffic Management suggests the transfer of marked school crossings from intersections to mid-block locations. This will reduce the complexity of the crossing maneuver for the student pedestrians. At mid-block crossings, fewer vehicle movement options are available and therefore creating a simpler situation. (*78*)

Recommendation: The relocation of pedestrian crossings may be helpful on local streets, but probably is not applicable to the higher speed traffic on state routes. Motorists are ready to stop at intersection crossings, but they are not accustomed to stopping for pedestrians at mid-block locations.

PUBLIC EDUCATION FOR PEDESTRIAN SAFETY

"Kill Your Speed" TV Ads Showing Actual Video Of Child Pedestrian Collision Victims (United Kingdom)

The Department of the Environment, Transport and the Regions (DETR)- formerly Department of Transport in the United Kingdom- is responsible for television shock ads that show actual video footage of child pedestrian victims. These messages stress driving at appropriate speeds and compliance with speed limits. (*65*)

Walk Smart Baltimore Is A Test Program To Use Education, Enforcement, And Engineering To Address The Problem Of Collisions Involving Pedestrians Who Have Used Alcohol

Data analysis of pedestrian collisions in Baltimore, Maryland, has revealed that for the years of 1990-1992 over 40% of adult pedestrians (specified as age 14 and older) involved in collisions had been drinking. A study of the development, implementation, and evaluation of a program to address the problem of alcohol-involved pedestrian collisions is being performed in Baltimore by Dunlap and Associates, Inc. with the National Highway Traffic Safety Administration, USDOT. (*88*)

Some of the countermeasures for this program include:

- Public Information and Education
- Police Involvement
- Server/Seller Responsibility
- Traffic Engineering in Problem Areas

"Drink Safe Walk Safe," Public Campaign To Educate About Dangers Of Pedestrians Under The Influence (South Sydney Australia)

The "Drink Safe Walk Safe" program incorporated engineering, education, environment and enforcement to help combat the problem of alcohol related pedestrian collisions. (South Sydney Packet) This program is similar to "Walk Smart Baltimore."

Recommendation: Caltrans is currently pursuing a pedestrian safety publicity campaign. It is recommended that public education be focused on remedies for the specific causes of most pedestrian collisions. For example, since almost 40% of state route pedestrian collisions occur on freeways, the public campaign should remind people to stay off of freeways. Another focus should be to educate motorists on several items:

1. unmarked crosswalks are legal crosswalks and
2. pedestrian right-of-way needs to be honored at any crosswalk.

TRAFFIC CALMING

Traffic Calming And Non-motorized Travel

Traffic calming has become a feature for improving the quality of life on local streets—reducing air and noise pollution and creating safer streets for pedestrians, bicyclists, and children. The public likes traffic calming for these real and perceived benefits. Traffic calming, as opposed to regulatory measures, is intended to be self-enforcing.

Pedestrians and bicyclists can benefit from traffic calming measures. One objective of traffic calming is to return the use of the roads to the residents. Local streets should accommodate local traffic at slow speeds. Bicycles should be able to share the street and pedestrians should be able to cross easily.

Streets classified as collectors should allow comfortable shared use with bicycles and pedestrians, should have frequent opportunities to cross, and have buffered sidewalks.

Arterial streets should accommodate mostly through-traffic and allow bicycle travel in bicycle lanes. Pedestrians should have buffered sidewalks and be able to cross without unreasonable delays. (*36*)

Recommendation: These traffic calming measures are more applicable to local roads and collectors and, therefore, are not generally applicable on state routes and higher speed arterials.

Curb Extensions

Chokers and bulbouts reduce the width of the street for the purpose of calming traffic speeds. Chokers (also known as two-lane slow points) can be curb extensions or islands at mid-block locations. The curb extension can be applied to one or both sides of the roadway.

Bulbouts (also known as neckdowns, bulbs, nubs, and gateways) are curb extensions at intersection locations.

Curb extensions provide added area for pedestrians and landscaping. Curb extensions at crossing locations increase the motorists' ability to see pedestrians and also the pedestrians' ability to see approaching traffic. These treatments reduce the exposed crossing distance for pedestrians.

Recommendation: Curb extensions are more applicable to local roads and collectors than on state routes.

Raised Crosswalks

A raised crosswalk is a combination of a speed hump and crosswalk. The cross-section of a raised crosswalk is similar to a speed hump with the exception of a flat surface at the top portion of the hump. The pedestrian is provided a level walking surface for crossing the roadway.

The flat section often has a brick or other textured surface. Markings and signs distinguish the raised pedestrian crosswalk. Raised crossings are being used in Sparks, Nevada, Beaverton and Eugene, Oregon, Tallahassee, Florida, and Montgomery County, Maryland.

Recommendation: Raised crosswalks are more applicable to local roads and collectors and should not be used on state routes.

TRANSIT CONSIDERATIONS

Transit

Bus bulbs are extensions of the curb through the parking lane to the edge of a through traffic lane at transit stop locations. Bus bulbs serve three main purposes: (*89*)

1. Bulbs provide additional space for transit amenities such as shelters and benches;
2. Bulbs allow through pedestrian travel at congested stops; and
3. Bulbs eliminate the bus-weaving maneuver necessary to enter bays.

A study in San Francisco, California, found the available waiting area around the bus shelter increased 64%. An increase of both available area per pedestrian and LOS was measured. The greatest distinction occurred during the period passengers board and alight. Conflicting movements, streams, and walking speeds around the cueing area are potential pedestrian congestion problems. The available area increased allowing pedestrians to pass slower traffic easier, cross the conflicting flows easier, and pass standing pedestrians easier. (*89*)

Recommendation: It is recommended that warrants be developed for bus bulbs based upon vehicular and pedestrian demand. Bus bulbs may be applicable on busy urban streets that are designated as state routes.

Supplementary Ultraviolet Head Lights Effect On Pedestrian Visibility

A study to evaluate the effectiveness of supplementary ultraviolet lights on nighttime driving visibility was conducted ("Ultraviolet Headlamp Technology for Nighttime Enhancement of Roadway Markings and Pedestrians" TRB No. 1636.) Most laundry detergents contain fluorescent whitening agents that tend to make the

washed clothing fluoresce in ultraviolet light. The study found that pedestrians were visible at distances increased by over 90% with the supplementary ultraviolet lights.

Recommendation: Caltrans should recommend that this subject be pursued at a national level. This unique idea appears promising based on the single study reviewed.

5.0 FINDINGS AND CONCLUSIONS

There are numerous conclusions that had been developed and organized into four categories including: general recommendations, practices for Caltrans to continue, practices requiring more study, and practices that could be implemented.

General Recommendations

The first general recommendation for Caltrans involves the findings regarding the frequency and severity of pedestrian collisions. These findings need to be utilized in all considerations regarding policies and practices associated with pedestrian safety. It has been established that pedestrian involved fatal collisions occur at a rate of about 23 times more than non-pedestrian fatal collisions on the state highway system. Adding in the collisions on local streets and roads this factor is reduced to about seven times. Consequently, for warrants involving pedestrians traveling along or crossing state routes it would be appropriate to consider this difference in the severity of pedestrian and vehicle collisions.

Secondly, since there are many recommendations below that affect pedestrian safety, it would be appropriate for a statewide conference of a number of Caltrans engineers involved in traffic safety to be convened. These engineers should possess experience involved in urban, suburban, and rural traffic operational conditions. Prior to the conference they should be familiar with pedestrian collisions within their district including reading the law enforcement officer collision reports. The expertise that they possess should provide excellent guidance on the appropriateness of many of the following recommendations. This is the second general recommendation.

The final general recommendation involves data collection. In reviewing the statewide pedestrian collision data provided by Caltrans, a major concern was the relative pedestrian exposure associated with the various characteristics of these pedestrian involved collisions. As a result, for Caltrans to maintain a strong commitment to pedestrian safety, it will be extremely helpful to provide data on pedestrians. To accomplish this, it is recommended that a number of statewide locations in urban and suburban areas be identified as "control" locations. Through the use of video technology these locations can be filmed 24 hours a day, four times during a given year, for approximately three consecutive days. This would allow hourly factors to be developed that could be used on any state highway in urban or suburban areas. The advantage of factors will be the ability for the districts to count pedestrians manually for two or three hours and then a 24-hour pedestrian count could be estimated. This would enable collision rates involving pedestrian travel to be calculated. Without pedestrian exposure information, the effectiveness of practices to improve pedestrian safety cannot be determined.

Practices for Caltrans to Continue

Previously, several practices have been discussed that Caltrans has already implemented. The following is a list of practices that are recommended for Caltrans to continue:

- It is recommended that Caltrans continue to follow the ADA requirements, specifically the requirements regarding the impacts of obstacles in the sidewalk

and buffers. As feasible, buffers should also be provided along higher speed, non-freeway, state routes.

- It is recommended that Caltrans maintain the policy of not encouraging pedestrians to travel upon highway shoulders, especially on high-speed highways.
- Caltrans is currently pursuing a pedestrian safety publicity campaign. It is recommended that the campaign continue. In addition, it is recommended that public education be focused on remedies for the specific causes of most pedestrian collisions.
- Current practices in the Highway Design Manual appear adequate regarding specific warrants for grade-separated structures.

Practices for Caltrans to Study

The following is a list of potential practices that are recommended for Caltrans study to determine if each practice could be implemented:

- The 2000 MUTCD allows for the optional use of passive pedestrian detection equipment (PUFFINs) to avoid using a lower walking speed to determine the pedestrian clearance time. This device would need to have further study conducted before it could be implemented.
- Accommodating pedestrians at roundabouts is a subject worthy of study and formal research. Roundabouts are gaining acceptance as a method of intersection traffic control.

Practices for Caltrans to Implement

The following is a list of practices that are recommended for Caltrans to implement with little or no additional study:

- It is recommended methods be developed to estimate pedestrian demand for state routes in urban areas without access control. This system should classify highway projects as having "low," "medium," or "high" pedestrian demand. Some detailed qualitative guidelines need to be established to assist in these classifications. The guidelines should allow for "generated" pedestrian travel as "pedestrian friendly" improvements are made.
- The topics of pedestrian Capacity and Level of Service are important and should be considered for state routes without access control and in urban areas. Locations that are identified as having an estimated "high" pedestrian demand will require careful analysis. The analysis will determine, through application of capacity and level of service computations, if space allocated to pedestrian travel should exceed minimum standards. Caltrans should be an active participant in the HCM subcommittees dealing with pedestrian matters.
- It is recommended that Caltrans develop a rating system for sidewalk maintenance.
- Caltrans should conduct a formal review of the US DOT policy statement, regarding funding for sidewalk construction. The Highway Design Manual should then be revised to incorporate the guidance of the US DOT.
- A program to remove obstacles in "high" pedestrian demand areas needs to be established. The obstacles must be removed when reconstruction occurs. Cost should be given proper consideration when investigating the feasibility of removing obstacles.

- For the specific topic of buffers, California should adopt appropriate guidelines to protect pedestrians from high-speed vehicle traffic.
- On highways where pedestrian demand is "medium" to "high" separate paths or sidewalks are recommended for pedestrians. Coordination with local governments should be required.
- It is appropriate to develop policies on alternate types of crosswalk markings. Applicable issues would include: specifications, warrants, and consistency versus overuse.
- The in-pavement crosswalk lighting technique should be considered for use at existing mid-block crosswalks where it is important that motorists see the presence of the crosswalk.
- It is recommended that demonstration installations of internally illuminated crosswalk warning signs be used at sites where there is a problem with pedestrian collisions.
- It is recommended that demonstration installations of passive pedestrian detection devices be used.
- It is appropriate to review the pedestrian crossing speed standard established in the Traffic Manual. The Traffic Manual should allow for walking speed as low as three feet per second where conditions warrant.
- Countdown timers on pedestrian signal heads would be appropriate where large pedestrian traffic volumes occur.
- Statewide collision data suggests that there may be a problem with pedestrian collisions involving turning vehicles. Auditory messages may be effective when there is high pedestrian volumes, high turning vehicle volumes, or a history of pedestrian versus turning vehicle collisions. The use of the Pedestrian Scramble System usually reduces pedestrian versus turning vehicle collisions.
- Audible devices to assist the visually impaired are to be installed whenever there is an observed demand or a request for their presence. The device used by San Francisco appears promising.
- To encourage pedestrian travel, Caltrans should automatically install pedestrian signal heads and activation in urban and suburban areas, rather than using warrants. As a minimum, all traffic signal systems should be "plumbed" for pedestrian signal heads and pedestrian detector devices.
- Since roundabouts have been, and are being, considered on state routes, the following are some preliminary recommendations independent of formal research proposed previously:
  - If roundabouts were to be used with high pedestrian and vehicular travel, grade-separated pedestrian crossings would be necessary.
  - Pedestrian signals are not recommended for use with roundabouts. If grade separated crossings are not feasible at roundabouts with high travel demand, pedestrian signals may be considered at sites sufficiently removed from the roundabout.
  - Pedestrian crossings should not be located close to the entrance to the roundabout.

  - Signs warning motorists of pedestrians should be located within roundabouts as well as on the approaches.
- It is recommended that highway crossings be at a right angle to the railroad tracks. This detail of railroad crossings should be incorporated into the Highway Design Manual.
- Over-crossings are preferred to under-crossings due to concerns related to crime, vandalism, drainage, high water tables, relocation of utilities, and higher construction costs.
- While the current practices outlined in the Highway Design Manual appear adequate, as it is very comprehensive, the severity of pedestrian collisions versus other collisions (7 to 17 times) should be emphasized.
- Caltrans should certainly coordinate and cooperate with local and law enforcement agencies regarding school safety programs.
- It is recommended that warrants be developed for bus bulbs based upon vehicular and pedestrian demand. Bus bulbs may be applicable on busy urban streets that are designated as state routes where on-street parking is allowed.
- Caltrans should recommend that the subject of ultraviolet headlights be pursued at a national level. This unique idea appears promising based on the single study reviewed.

APPENDIX A: REFERENCES

1. *Pedestrian Safety Task Force.* California Department of Transportation, Sacramento, California, 1999.

2. *Traffic Engineering Handbook.* 4th Edition. Institute of Transportation Engineers, Washington D.C., 1992.

3. National Center for Statistical Analysis. *Traffic Safety Facts 1998, Pedestrians.* Report DOT HS 808 958. National Highway Traffic Safety Administration, U.S. Department of Transportation. undated. http://www.nhtsa.dot.gov/people/ncsa/pdf/Ped98.pdf. Accessed June 8, 2000.

4. National Center for Statistical Analysis. *Traffic Safety Facts 1998, Alcohol.* Report DOT HS 808 950. National Highway Traffic Safety Administration, U.S. Department of Transportation. undated. http://www.nhtsa.dot.gov/people/ncsa/pdf/Alcohol98.pdf. Accessed June 8, 2000.

5. *Vehicle Code.* State of California. Undated. http://www.leginfo.ca.gov/calaw.html. Accessed June 2, 2000.

6. *Highway Design Manual.* California Department of Transportation, Sacramento, California, 1997.

7. *Traffic Manual.* California Department of Transportation, Sacramento, California, 1998.

8. *Maintenance Manual.* California Department of Transportation, Sacramento, California, 1998.

9. *Projects Development Procedures Manual.* California Department of Transportation, Sacramento, California, 1999.

10. *California Streets and Highways Code.* State of California. undated. http://www.leginfo.ca.gov/calaw.html. Accessed June 8, 2000.

11. *California Environmental Quality Act.* State of California. June 21, 1999. http://ceres.ca.gov/topic/env_law/ceqa/stat/. Accessed June 2, 2000.

12. *Construction Manual.* California Department of Transportation. June 30, 1999. http://svhqsgi4.dot.ca.gov/hq/construc/manual/cover3.htm. Accessed September 26, 2000.

13. *School Trip Safety Program Guidelines.* Institution of Transportation Engineers. 1984.

14. *Legislative Counsel's Digest.* State of California. February 26,1999. AB 1475 Assembly Bill - CHAPTERED Accessed December 19,2000.

15. *Legislative Counsel's Digest.* State of California. February 26,1999. http://info.sen.ca.gov/pub/99-00/bill/asm/ab_1551-1600/ab_1573_bill_19991010_chaptered.html Accessed December 19,2000.

16. *Legislative Counsel's Digest.* State of California. March 16,2000. http://info.sen.ca.gov/pub/99-00/bill/sen/sb_2151-2200/sb_2185_bill_20000908_chaptered.html Accessed December 19,2000.

17. *Legislative Counsel's Digest.* State of California. February 24,2000. http://info.sen.ca.gov/pub/99-00/bill/asm/ab_2501-2550/ab_2522_bill_20000929_chaptered.html Accessed December 19,2000.

18. *Pedestrian Accessibility Guidelines for Highway Projects, Draft.* Design Information Bulletin 82, California Department of Transportation, Sacramento, California, (publication pending).

19. Deputy Directive. *Accommodating Non-Motorized Travel*, DD-64, California Department of Transportation, March 26, 2001.

20. Encyclopedia Britannica. Roads and Highways. http://www.britannica.com Accessed July 2001

21. National Center for Statistics and Analysis. Traffic Safety Facts 1998—Pedestrians. Report DOT HS 808 958. National Highway Traffic Safety Administration, U.S. Department of Transportation http://www.nhtsa.dot.gov/people/ncsa/pdf/Ped98.pdf Accessed June 2000.

22. Pedestrian Safety Task Force, California Deparment of Transportation, Sacramento, California, 1999.

23. National Center for Statistics and Analysis. *Traffic Safety Facts 1999—Pedestrians.* http://www.nhtsa.dot.gov/people/ncsa/pdf/newPed99.pdf Accessed May 2001.

24. *National Bicycling and Walking Study Five-Year Status Report.* April 1999 http://www.fhwa.dot.gov/environment/bikeped/Study.htm Accessed June 2000

25. Research Triangle Institute. *1990 Nationwide Personal Transportation Study.* http://www-cta.ornl.gov/npts/1990/index.html. Accessed October 2001

26. Schwartz, WL, Porter, CD, Payne, GC, Suhrbeir JH, Moe, PC, and Wilkinson III, *Guidebook on Methods to Estimate Non-Motorized Travel: An Overview of Methods* Report FHWA-RD-98-165, FHWA US Department of Transportation July 1999

27. Rouphail, N., Hummer, J., Millazzo II, J, and Allen, P. *Capacity Analysis of Pedestrian and Bicycle Facilities: Recommended Procedures for the "Pedestrians" Chapter of the Highway Capacity Manual.* Report FHWA-RD 98-107. February 1998

28. Rouphail, N., Hummer, J., Millazzo II, J, and Allen, P. *Capacity Analysis of Pedestrian and Bicycle Facilities: Recommended Procedures for the "Signalized Intersection" Chapter of the Highway Capacity Manual.* U.S. Department of Transportation Report FHWA-RD 98-106. February 1998

29. *Highway Capacity Manual*, Transportation Research Board, National Research Council Washington DC 1988

30. Beneficial Designs Inc., *Designing Sidewalks and Trails for Access: Review of Existing Guidelines and Practices (Part I of II)*, U.S. Department of Transportation. Publication No.: FHWA-HEP-99-006. July 1999

31. OTAK. *Pedestrian Facilities Guidebook.* Washington State Department of Transportation. Washington, September1997.

32. Zeeger, Charles V., Chair, Traffic Engineering Council Committee TENC-5A-5. *Design and Safety of Pedestrian Facilities.* Institute of Transportation Engineers. Washington D.C. March 1998.

33. *Everyone Is a Pedestrian: New York State Pedestrian Safety Engineering Toolbox, Draft Guidelines.* New York Department of Transportation, June 1996.

34. Mater Planning Consortium, Inc., *Statewide Bicycle and Pedestrian Master Plan, Louisiana Department of Transportation and Development.* May 1998.

35. *Pedestrian Facility Guidelines.* Missouri Department of Transportation. 1999.

36. *Oregon Bicycle and Pedestrian Plan.* 2nd Edition. Oregon Department of Transportation, Salem, Oregon, 1995.

37. University of North Carolina Highway Safety Research Center. *Florida Pedestrian Planning and Design Handbook.* Florida Department of Transportation, April 1999.

38. RBA Group, The. *Pedestrian Compatible Planning and Design Guidelines.* New Jersey Department of Transportation, April 1996.

39. *Portland Pedestrian Design Guide.* City of Portland Office of Transportation. October 1998

40. *Glens Falls Sidewalk Evaluation and Rating Manual.* Adirondack/Glens Falls Transportation Council, Ft. Edward NY, July 1999.

41. AASHTO, *Geometric Design of Highways and Streets.* Washington DC, 1994.

42. Vermont State Roadway Design Standards. State of Vermont Agency of Transportation. October 1997. http://www.aot.state.vt.us/projdev/standards/statabta.htm

43. AASHTO, *Geometric Design of Highways and Streets,* Washington DC, 1990.

44. *Bicycle and Pedestrian Plan.* State of Vermont Agency of Transportation. December 1998. Accessed 7-25-00 http://www.aot.state.vt.us/planning/BIKEPED.htm

45. Manual on Uniform Traffic Control Devices, US Department of Transportation Federal Highway Administration, 1988

46. Zegeer, Charles, UNC Highway Safety Research and Consultants: Lagerwey, Peter A., Cynecki, Mike, Ross, Arthur, and Ronkin, Michael. *Priorities and Guidelines for Providing Places for Pedestrians to Walk Along Streets and Highways* DRAFT. Prepared for Federal Highway Administrantion, September 1999.

47. *The Traffic Safety Toolbox*, "Designing for Pedestrians" Institute of Transportation Engineers. 1993

48. Comprehensive Pedestrian Crossing Policy—City of San Diego Council Policy City of San Diego April 1990

49. National Center for Bicycling and Walking. Bridges. Accessed March 2001 http://www.bikefed.org

50. *Planning and Designing Local Pedestrian Facilities.* North Carolina Department of Transportation. February 1997

51. Turner Fairbanks Highway Research Center. Pedestrian and Bicycle Crash Types of the Early 1990's. Publication No. FHWA-RD-95-163. U.S. Department of Transportation 1995

52. Florida Department of Transportation, *Trail Intersection Design Guidelines*, no publisher, no date.

53. *Vehicle* Code. State of California. Undated. http://www.leginfo.ca.gov/calaw.html Accessed August 2000

54. Zeeger, Stewart, and Huang, *Safety Effects of Marked VS Unmarked Crosswalks at Uncontrolled Crossing Locations.* Draft 1999

55. Miller, Rock and Sutaria, T.C. *City of Santa Ana Pedestrian Safety Study* March 2001. Accessed April 2001 http://www.katzokitsu.com

56. ITE Journal, "*Darn Good Ideas*" (Section on Double Ladder Crosswalks), Washington DC February 1996

57. Von Houten, Ron, Malenfant, J.E., *Canadian Research on Pedestrian Safety* FHWA-RD-99-090 U.S. Department of Transportation 1999

58. *Safety Benefits of Advance Stop Lines at Signalized Intersections: Results of a Field Evaluation* ITE Journal September 2000

59. Logan Simpson & Dye. *Pedestrian Area Policies and Design Guidelines.* Maricopa Association of Governments, October 1995.

60. Zeeger, Stewart, and Huang, *The Effects of Innovative Pedestrian Signs on Pedestrian and Motorist Behavior at Unsignalized Locations: A Tale of Three Treatments.*

61. *Development of an Experimental System for Pedestrian Warning,* Westernite March-April 1998

62. *Improving Pedestrian Safety at School Crossings.* www.xwalk.com/walt.htm

63. *An Evaluation of a Crosswalk Warning System Utilizing In*-Pavement Flashing Lights

64. Godfrey, David, Mazzell, *Tony, Kirkland's Experience With In-Pavement Flashing Lights At Crosswalks*

65. Davies, David G. *Research, Development, and Implementation of Pedestrian Safety Facilities in the United Kingdom.* Report FHWA-RD-99-089. FHWA,U.S. Department of Transportation, 1999.

66. Darn Good Ideas, *ITE Journal*, Vol. 68, No. 10, October 1998.

67. Knoblauch, Pietrucha, and Nitzburg, *Field Studies of Pedestrian Walking Speed and Start-Up Time*, Transportation Research Board.

68. City of San Francisco, Department of Parking and Traffic Current Pedestrian Safety Program May 2000

69. *Three-Second Head Start Gives Pedestrian Advantage at Intersection* Auto and Road User Journal

70. Leaf, W.A., Preusser, *Literature Review on Vehicle Travel Speeds and Pedestrian Injuries.*

71. Robinson, Bruce *Roundbouts: An Informational Guide* US Department of Transportation Federal Highway Administration FHWA-RD-00-067, 2000

72. Taekratok, Thaweesak, *Modern Roundabouts for Oregon,* Oregon Department of Transportation OR-RD-98-17, Salem, Oregon, 1998

73. Ewing, Reid, *Traffic Calming: State of the Practice* US Department of Transportation Federal Highway Administration, *FHWA-RD-99-135 1999*

74. Fehr & Peers and Associates, Inc. *www.trafficcalming.org* Accessed June 2000

75. *Guidelines for the Design and Application of Speed Hump—A Recommended Practice.* Institute of Transportation Engineers, Washington DC 1997

76. *Recommended Practice—School Trip Safety Program Guidelines*, Institute of Transportation Engineers, 1984.

77. *ITE Journal*, Vol. 69, No. 11, November 1999.

78. http://www.trans.ci.portland.or.us/Traffic_Management/Trafficcalming/reports /School/school.htm

79. Traffic Safety Corp. *http://www.xwalk.com/zone.htm* Accessed April 2001

80. *Access to Intersection Traffic Control Information* The American Council of the Blind 1999

81. Bentzen, Billie L, Tabor, Lee *Access for Everyone: Meeting the ADA*, The American Council of the Blind http://www.acb.org/pedestrian/signals.html Accessed March 2001

82. Bentzen, Billie L, Tabor, Lee *Information Requirements at Intersections* The American Council of the Blind http://www.acb.org/pedestrian/signals.html Accessed March 2001

83. Bentzen, Billie L., *Accessible Pedestrian Signals* The American Council of the Blind http://acb.org/pedestrian/phd2a.html Accessed March 2001

84. Bentzen, Billie L., Tabor, Lee. *Determining When to Install* The American Council of the Blind http://www.acb.org/pedestrian/signals.html Accessed March 2001

85. Georgia Municipal Association, *Augusta's Audible Pedestrian Signals*, March 2000, http://www.gmanet.com/research/resources/publicsafety.pedestrian.shtml, Accessed April 2000

86. National Center for Bicycling and Walking. Amenities. Accessed March 2001 http://www.bikefed.org

87. Tillett, Linnaea, Pedestrian Lighting: A New Approach, National Center for Bicycling and Walking, Washington DC 1998

88. Walk Safe Baltimore Pedestrian Packet, Baltimore, Maryland

89. Fitzpatrick, Kay, Hall, Kevin, Farnsworth, Stephen, Finley, Melisa. *Evaluation of Bus Bulbs* TCRP Report 65 Transit Cooperative Research Program Washington DC 2001

90. Cairney, Peter. *Pedestrian Safety in the Austraila.* Report FHWA-RD-99-093. FHWA,U.S. Department of Transportation, 1999.

91. Zegeer, C. V., Stutts, J. C., and Hunter, W. W .Safety Effectiveness of Highway Design Features, Volume VI—Pedestrian and Bicyclists, FHWA Report No. FHWA-RD-91-049, 1992

92. Smith, S. A., Opiela, K. S., Impett, L.L.., Pietrucha, M. T. Knoblauch, R. L. NCHRP Report 294A—Planning and Implementing Pedestrian Facilities in Suburban and Developing Rural Acreas. Transportation Research Board, NRC, Washington D.C. 1987

93. *Berkeley Pedestrians Get Traffic Flags*. Sacramento Bee. May 12, 2001 Vol. 289 No.94

94. Bicycle And Pedestrian Provisions Of The Federal-Aid Program As Amended By The Transportation Equity Act For The 21st Century A Summary. U.S. Dept. of Transportation, Federal Highway Administration, 1998

95. TEA-21 Transportation Equity Act for the 21st Century (Section 1202). Federal Highway Administration. http://www.fhwa.dot.gov/tea21/h240subb.htm#1202

96. TEA-21 Transportation Equity Act for the 21st Century. Federal Highway Administration. http://www.fhwa.dot.gov/tea21/

97. *Design Guidance: Accommodating Bicycle and Pedestrian Travel: A Recommended Approach.* US Department of Transportation. Federal Highway Administration. www.fhwa.dot.gov/environment/bikeped/Design.htm March 2000, Accessed May 2001

98. Gibby, A. Reed, Stites, Janice, Thurgood, Glen S., Ferrara, Thomas C., *Evaluation of Marked and Unmarked Crosswalks at Intersections in California.* California State University, Chico. 1994

99. California Department of Finance. *Population and Percent Distribution, by Age and by Race and Hispanic Orgin* http://www.dof.ca.gov/html/fs_data/stat-abs/sec_B.htm Accessed July 2001

100. Robinson, Bruce W., et. al., *Roundabout: An Informal Guide.* Report FHWA-RD-00-067. FHWA, U.S. Department of Transportation, 2000.

APPENDIX B: INDEX OF PEDESTRIAN CODES AND MANUALS